TECHNIDATA

HAND BOOK

By EDWARD LUPTON PAGE, B.Sc.

ENGINEERING

CHEMISTRY

PHYSICS

MECHANICS

MATHEMATICS

DEFINITIONS, LAWS, THEORY,

FORMULAS AND TABLES

CONDENSED FOR READY REFERENCE

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PREFACE

This book is a condensed classified summary of the useable information on the fundamental exact sciences. Whoever uses mathematics, physics, chemistry, mechanics or engineering will find this book of inestimable value.

As a student, the author found himself carrying around too many books and spending too much time looking through them for information which often proved to be scattered elsewhere. He compiled for his own use the data contained in this book which in its compactness contains nearly all the essential information needed on these subjects.

The value of this book lies in the following reasons:

FIRST:- Derivations, unnecessary or little used data, and long explanations have been omitted.

SECOND:- Formulas with short explanations of terms have the units and common constants given.

THIRD:- The content is well organized, compact, fundamental, and will not go out of date.

FOURTH:- Data scattered in many places is here all combined for quick, easy reference.

Edward Lupton Page

CONTENTS

MATHEMATICS

Algebra
Geometry
Trigonometry
Analytic Geometry
Calculus

Tables

SYMBOLS

c = circumference — A = area
d = diameter or diag. — b = base
g = accel. due to gravity. 32.2 ft./sec.^{2} — p = perim.
r = radius
h = perpendicular ht. — v = volume
$y = c$ = dist. from neut. axis to extreme fibre — s = surface
CG = center of gravity
Z = section modulus $= \frac{I}{c}$
I = moment of inertia
I_p = polar mom. of inertia
I_1, about neutral axis thru cg
I_{22}, about axis 22.
ρ = rho radius of gyration $= \sqrt{I/m}$ or $\sqrt{I/A}$
l = slant height — ∞ = infinity
s = side surface — # = pounds
T = total surface — π = pi = 3.1416
ω = omega = angle in radians
! = factorial i.e. $3! = 1+2+3$

ALGEBRA

$a \cdot a = a^2$ — $\sqrt{2} = 1.414$
$a^n b^n = (ab)^n$ — $\sqrt{3} = 1.732$
$a^n \cdot a^m = a^{n+m}$ — $\sqrt{5} = 2.236$
$a^0 = 1$
$a^2 - b^2 = (a+b)(a-b)$
$(a+b)^2 = a^2 + 2ab + b^2$
$(a-b)^2 = a^2 - 2ab + b^2$
$(x+a)(x+b) = x^2 + (a+b)x + ab$
$(ax+b)(cx+d) = acx^2 + (ad+bc)x + bd$
$\left(\frac{1}{a}\right)^n = \frac{1}{a^n} = a^{-n}$
$(a^n)^m = a^{nm}$
$a^3 \pm b^3 = a \pm b(a^2 \mp ab + b^2)$
$(a \pm b)^3 = a^3 \pm 3a^2b + 3ab^2 \pm b^3$
$(a+b+c)^2 = a^2 + b^2 + c^2 + 2ac + 2ab + 2bc$

ALGEBRA

$\sqrt{a}\sqrt{a}$ or $a^{\frac{1}{2}}a^{\frac{1}{2}} = a$
$\sqrt[n]{a^n} \quad (a^n)^{\frac{1}{n}} = a$
$\sqrt[n]{a^m} = (\sqrt[n]{a})^m = a^{\frac{m}{n}}$
$\sqrt[m]{\sqrt[n]{a}} = \sqrt[mn]{a} = \sqrt[n]{\sqrt[m]{a}}$
$\sqrt{a} + \sqrt{b} = \sqrt{a+b+2\sqrt{ab}}$
$\sqrt[n]{a}\sqrt[n]{b} = \sqrt[n]{ab}$
$\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$
$\sqrt[n]{\frac{1}{a}} = \frac{1}{\sqrt[n]{a}} = \frac{1}{a^{\frac{1}{n}}} \quad a^{-\frac{1}{n}}$

Quadratic formula
$ax^2 + bx + c = 0$
$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$x^3 + ax + b = 0$
$\left(-\frac{b}{2} + \sqrt{\frac{a^3}{27} + \frac{b^2}{4}}\right) + \left(-\frac{b}{2} - \sqrt{\frac{b^2}{27} + \frac{b^2}{4}}\right)$
To reduce $x^3 + px^2 + qx + r = 0$ to $x^3 + ax + b = 0$, subst. $x_1 = \left(x - \frac{p}{3}\right)$.

Logarithms:
$a \cdot b = x$, $\log a + \log b = \log x$
$\frac{a}{b} = x$, $\log a - \log b = \log x$
$a^3 = x$, $3 \log a = \log x$
$\sqrt[3]{a} = x$, $\frac{\log a}{3} = \log x$
$y = \log_a x$, $x = a^y$ $\quad e = 2.718$
$\log_a a^x = x$ $\quad \log_{10} x = .4343 \log_e x$
$a^{\log_a x} = x$ $\quad \log_e x = 2.3025 \log_{10} x$

Proportions
If $\frac{a}{b} = \frac{c}{d}$, then $\frac{a+b}{b} = \frac{c+d}{d}$

$\frac{a-b}{b} = \frac{c-d}{d}$

$\frac{a+b}{c+d} = \frac{a-b}{c-d}$

ALGEBRA

Sum of numbers

$\Sigma(n) = 1+2+3+4+\cdots+n = n(n+1)/2$

$\Sigma(n^2) = 1^2+2^2+3^2+\cdots+n^2 = n(n+1)(2n+1)/6$

$\Sigma(n^3) = 1^3+2^3+3^3+\cdots+n^3 = n^2(n+1)^2/4$

Arithmetical progression

$l = a + (n-1)d$

$s = \frac{n}{2}\left[2a+(n-1)d\right]$

$s = \frac{n}{2}(a+l)$

Geometric progression

$l = ar^{n-1}$

$s = a\frac{r^n-1}{r-1}$

$s = a\frac{(1-r^n)}{1-r}$

$s = \frac{lr-a}{r-1}$

$n = \infty,\ r^2<1$

$s = \frac{a}{1-r}$

a = first term
l = last term
d = common diff.
n = no. of terms
s = sum of n terms
r = common ratio

Factorials

$n! = e^{-n}n^n\sqrt{2\pi n}$ approx.

Permutations

$M = n(n-1)(n-2)\cdots(n-P+1)$

where M = no. of permutations of n things taken P at a time

Combinations

$M = \frac{n(n-1)(n-2)\cdots(n-P+1)}{P!}$

$M = \frac{n!}{P!(n-P)}$

Series

Binomial

$(x+y)^n = x^n+nx^{n-1}y+\frac{n(n-1)}{2!}x^{n-2}y^2 + \frac{n(n-1)(n-2)}{3!}x^{n-3}y^3+\cdots$

ALGEBRA

Series

Taylor's

$f(x+h) = f(x)+hf'(x)+\frac{h^2}{2!}f''(x)+\frac{h^3}{3!}f'''(x)+\cdots$

Maclaurin's

$f(x) = f(0)+xf'(0)+\frac{x^2}{2!}f''(0)+\frac{x^3}{3!}f'''(0)$

Exponential

$e = 1+\frac{1}{1}+\frac{1}{2!}+\frac{1}{3!}+\frac{1}{4!}+\frac{1}{n!}+\cdots$

$e^x = 1+x+\frac{x^2}{2!}+\frac{x^3}{3!}+\frac{x^4}{4!}+\frac{x^n}{n!}+\cdots$

$a^x = 1+x\log a+\frac{(x\log a)^2}{2!}+\frac{(x\log a)^3}{3!}$

Miscellaneous

$\log(1+x) = x-\frac{x^2}{2}+\frac{x^3}{3}-\frac{x^4}{4}+\cdots$

$\sin x = x-\frac{x^3}{3!}+\frac{x^5}{5!}-\frac{x^7}{7!}+\cdots$

$\cos x = 1-\frac{x^2}{2!}+\frac{x^4}{4!}-\frac{x^6}{6!}+$

$(1+x)^n = 1+nx+\frac{n(n-1)}{2!}x^2+\frac{n(n-1)(n-2)}{3!}x^3+\cdots$

Interest

Simple

$P_n = Prn$

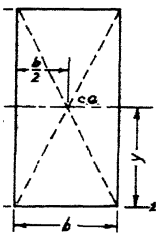
Compound

$P_n = p\left(1+\frac{r}{q}\right)^{nq}$

P_n = total after n years
P = principal
r = rate, i.e., 6%; $r=.06$
q = times/year compounded

PLANE FIGURES

Rectangle



$d = \sqrt{b^2+h^2}$

$A = bh$

$y = \frac{b}{2}$

$I = \frac{bh^3}{12}$

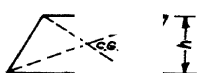
$Z = \frac{bh^2}{6}$

$\rho = \frac{h}{\sqrt{12}} = .2887\,h$

$I_{22} = \frac{bh^3}{3}$ $\quad Z_{22} = \frac{bh^2}{3}$

$\rho_{22} = \frac{h}{\sqrt{3}}$ $\quad I_p = \frac{bh}{12}(b^2+h^2)$

Parallelogram



bh

Trapezoid

$A = \frac{1}{2}(b+b')h$

c.g. at intersection of ef, line joining midpoints of par. sides & line joining c.g. of two triangles forming trapezoid.

Triangle

Right

$c = \sqrt{a^2+b^2}$

$A = \frac{1}{2}ab$

Any shape

$A = \frac{1}{2}bh$

$A = \sqrt{s(s-a)(s-b)(s-c)}$

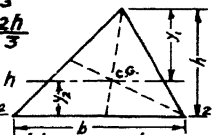
$s = \frac{1}{2}(a+b+c)$; a,b,c are sides

Triangle

$I = \frac{bh^3}{36}$; $y = \frac{h}{3}$

$Z = \frac{bh^2}{24}$; $y_1 = \frac{2h}{3}$

$\rho = \frac{h}{\sqrt{18}} = .236h$



$I_{22} = \frac{bh}{12}$; $Z_{22} = \frac{bh}{12}$; $\rho_{22} = \frac{h}{\sqrt{6}}$

c.g. at intersection of lines from vertex to midpoint of opposite side.

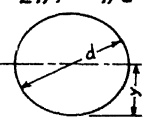
Equilateral

$h = \frac{b}{2}\sqrt{3} = .866h$

Circle

circumference $2\pi r = \pi d$

$A = \pi r^2 = \frac{\pi d^2}{4}$



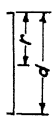
$I = \frac{\pi d^4}{64} = \frac{\pi r^4}{4}$

$Z = \frac{\pi d^3}{32} = \frac{\pi r^3}{4}$

$\rho = \frac{d}{4} = \frac{r}{2}$; $y = \frac{d}{2} =$

$I_p = J = \frac{\pi d^4}{32}$

Semicircle



$A = \frac{\pi r^2}{2} = 1.57r^2$

$I = .1098\,r^4$

$Z = .191\,r^3$; $\rho = .264r$

$\bar{y} = .5756r$; $y' = .424r$

Arc & sector

Arc length $= \frac{\text{central angle}}{180^\circ}\pi r$

$A = l_{arc}\frac{1}{2}r$ (central angle)

Regular polygon

$A = \frac{1}{2}ap$

a = apothem

p = perim.

Ellipse & parab. see analytic geom.

SOLID FIGURES

Prisms

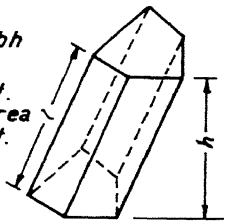
$S = pl$; $V = bh$

p = perim

l = slant ht.

b = base area

h = perp. ht.



Right prism

$S = ph$

$V = bh$

Pyramid

$S = \frac{1}{2}pl$ $\quad V = \frac{1}{3}bh$

c.g. $= \frac{1}{4}h$ from base (cone also)

Frustum of pyramid

$S = \frac{1}{2}(p+p')l$

p' = perim. of small base

$V = \frac{1}{3}h(B+B'+\sqrt{BB'})$

B' = area of small base

Cylinder of revolution

$S = 2\pi rh$

$T = 2\pi r(h+r)$

$V = \pi r^2 h$

$I = \frac{\pi d^4}{64}$

$I_\rho = \frac{\pi d^4}{32}$; $\rho_\rho = \frac{d^2}{8}$

Cone of revolution

$S = \pi rl$

$T = \pi r(l+r)$

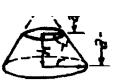
$V = \frac{1}{3}\pi r^2 h$

Frustum of cone

$S = \pi l(r+r')$

$V = \frac{1}{3}\pi h(r^2 + r'^2 + rr')$

c.g. $= \frac{3}{4}\frac{(a^2+aa'+a'^2)}{(a+a')}$ for cone frustum.

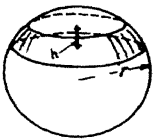


SOLID FIGURES

Sphere

$S = 4\pi r^2 = \pi d^2$

$V = \frac{4}{3}\pi r^3 = \frac{\pi d^3}{6}$



Zone

$S = 2\pi rh$

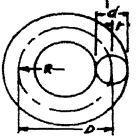
Spherical segment (one base)

$V = \pi h^2(r - \frac{h}{3})$

Torus

$S = 4\pi^2 Rr = \pi^2 Dd$

$V = 2\pi^2 Rr^2 = \frac{\pi^2 Dd^2}{4}$



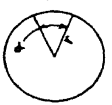
Spherical Sector

$V = \frac{2}{3}\pi r^2 h$

Lune (spherical wedge)

$S = \frac{\alpha}{90°}\pi r^2$

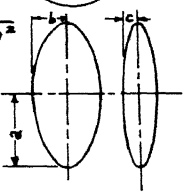
$V = \frac{\alpha}{90°}\frac{\pi r^3}{3}$



Ellipsoid

$S = \frac{4\pi}{\sqrt{2}} b\sqrt{a^2+b^2}$

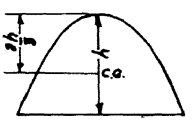
$V = \frac{4}{3}\pi abc$



Paraboloid

$V = \frac{1}{2}\pi r^2 h$

c.g. $= \frac{1}{3}h$ from base

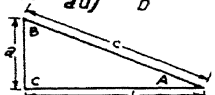


TRIGONOMETRY

sine $A = \frac{\text{opposite side}}{\text{hypothenuse}} = \frac{a}{c}$; $\csc = \frac{c}{a}$

cosine $A = \frac{\text{adjacent sd.}}{\text{hypothenuse}} = \frac{b}{c}$; $\sec = \frac{c}{b}$

tangent $A = \frac{\text{opp}}{\text{adj}} = \frac{a}{b}$; $\cot = \frac{b}{a}$



$\sin^2 A + \cos^2 A = 1$

$\sin^2 A = \cos^2 A \cdot \tan^2 A$

$\tan A = \frac{\sin A}{\cos A} = \frac{1}{\cot A}$

$\sin A = \frac{\tan A}{\sqrt{1+\tan^2 A}} = \frac{1}{\sqrt{1+\cot^2 A}} = \frac{1}{\csc A}$

$\cos A = \frac{\cot A}{\sqrt{1+\cot^2 A}} = \frac{1}{\sqrt{1+\tan^2 A}} = \frac{1}{\sec A}$

$\sin(90+A) = \cos A$; $\cos(90+A) = -\sin A$

$\tan(90-A) = -\cot A$

$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$

$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$

$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$

$\sin A \sin B = \frac{1}{2}\cos(A-B) - \frac{1}{2}\cos(A+B)$

$\cos A \cos B = \frac{1}{2}\cos(A-B) + \frac{1}{2}\cos(A+B)$

$\sin A \cos B = \frac{1}{2}\sin(A+B) + \frac{1}{2}\sin(A-B)$

$\tan A \tan B = \frac{\tan A + \tan B}{\cot A + \cot B}$

$\sin 2A = 2 \sin A \cos A$

$\cos 2A = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A$
$= 2\cos^2 A - 1$

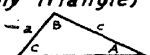
$\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$

$2\sin^2 A = 1 - \cos 2A$

$2\cos^2 A = 1 + \cos 2A$

Sine Law (any triangle)

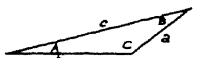
$\frac{a}{b} = \frac{\sin A}{\sin B}$



TRIGONOMETRY

Cosine Law (any triangle)

$a^2 = b^2 + c^2 - 2bc \cdot \cos A$



Isosceles triangle

$h = \sqrt{(a+\frac{1}{2}b)(a-\frac{1}{2}b)}$

Three sides given, solve for $\angle s$.

$\sin\frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}}$

$\cos\frac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}}$

$\tan\frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$

$s = \frac{1}{2}(a+b+c)$; a,b,c = sides

$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R$

R = radius circumscribed circle

Areas

$A = \frac{1}{2}bh = \frac{1}{2}ac \cdot \sin B$

$A = \frac{a^2 \sin B \sin C}{2\sin(B+C)}$

$A = \sqrt{s(s-a)(s-b)(s-c)}$

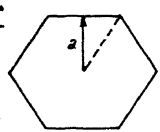
$s = \frac{1}{2}(a+b+c)$; a,b,c = sides

$A = \frac{abc}{4R}$; R = rad. circ. circle

Polygon of n sides

$A = \frac{na^2}{4}\cot\frac{180^\circ}{n}$

a = apothem



$A = \frac{1}{2}ap$

p = perimeter

$A = \frac{1}{2}pnl$

l = length of side

ANALYTIC GEOMETRY

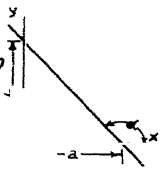
Straight line

General form

$$Ax + By + C = 0$$

Intercept form

$$\frac{x}{a} + \frac{y}{b} = 1$$



Slope form

$y = mx + b$; m = slope = $\tan\alpha$

$$\tan\alpha = \frac{m_2 - m_1}{1 + m_1 m_2}$$; α = angle betw. lines of sl. m_1, m_2

$$\cos\alpha = \frac{AA' + BB'}{\pm\sqrt{(A^2+B^2)(A'^2+B'^2)}}$$

α = angle betw. $Ax + By + C = 0$ & $A'x + By + C = 0$

Polar coordinates

$x = r\cos\theta$; $y = r\sin\theta$

$x^2 + y^2 = r^2$

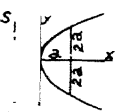
Parabola & properties

$$y^2 = 4ax$$

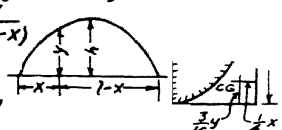
$$Cy^2 + Dx + Ey + F = 0$$

latus rectum = $4a$

$A = \frac{2}{3}$ area of enclosing rectangle



$$\frac{h}{\left(\frac{l}{2}\right)^2} = \frac{y}{x(l-x)}$$



Ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

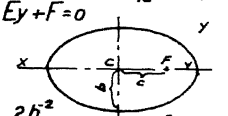
$$Ax^2 + Cy^2 + Dx + Ey + F = 0$$

$$b^2 = a^2(1 - e^2)$$

$$c = \sqrt{a^2 - b^2} = ae$$

$$d = \frac{a}{e}$$

latus rectum $\frac{2b^2}{a}$



C = center

F = focus; V = vertex; e = eccentricity

Circle (special case of ellipse)

$x^2 + y^2 = r^2$ r = radius

$Ax^2 + By^2 = c^2$ $A = B$

ANALYTIC GEOMETRY

Hyperbola

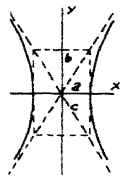
$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

$$Ax^2 - Cy^2 + Dx + Ey + F = 0$$

$$b^2 = a^2(e^2 - 1)$$

$$c = ae = \sqrt{a^2 + b^2}$$

asymptote - $y = \pm\frac{b}{a}x$



symmetrical about + term which is transverse axis.

Sphere

$$x^2 + y^2 + z^2 = a^2$$

Ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

Paraboloid

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = \frac{z}{c}$$

Hyperboloid

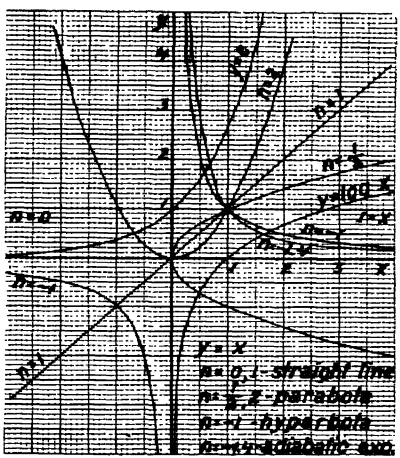
$$\frac{x^2}{a^2} \pm \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

\+ one sheet

\- two sheets

Cone (vertex at 0)

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 0$$



CALCULUS

Differentials

$dc = 0$ $\quad d\sin u = \cos u\, du$

$d(u+c) = du$ $\quad d\cos u = -\sin u\, du$

$d(cu) = c\,du$ $\quad d\tan u = \sec^2 u\, du$

$d(u+v) = du + dv$ $\quad d\cot u = -\csc^2 u\, du$

$d(uv) = u\,dv + v\,du$ $\quad du^n = nu^{n-1}du$

$d\left(\frac{u}{v}\right) = \frac{v\,du - u\,dv}{v^2}$ $\quad d\sqrt{u} = \frac{du}{2\sqrt{u}}$

$d \arcsin u = \frac{du}{\sqrt{1-u^2}}$

$d \arctan u = \frac{du}{1+u^2}$

$de^u = e^u du$; $d \log_e u = \frac{du}{u}$

$da^u = a^u \log_e a\, du$

$d(u^v) = u^v(1 + \log_e u)\, du$

$d(\log_a u) = \frac{du}{u \log_e a} = \frac{\log_a e}{u}\, du$

$d(u^v) = vu^{v-1}du + u^v \log u\, dv$

Integrals (add constant c to each)

$\int u^n du = \frac{u^{n+1}}{n+1}$ $\quad n \neq -1$

$\int \frac{du}{u} = \log_e u$

$\int \cos u\, du = \sin u$

$\int \sin u\, du = -\cos u$

$\int \sec^2 u\, du = \tan u$

$\int \csc^2 u\, du = -\cot u$

$\int \sec u \tan u\, du = \sec u$

$\int \csc u \cot u\, du = -\csc u$

$\int \tan u\, du = -\log \cos u$

$\int \cot u\, du = \log \sin u$

$\int \sec u\, du = \log(\sec u + \tan u)$

$\int \csc u\, du = -\log(\csc u + \cot u)$

$\int \frac{du}{\sqrt{a^2-u^2}} = \arcsin \frac{u}{a}$

$\int \frac{du}{a^2+u^2} = \frac{1}{a} \arctan \frac{u}{a}$

CALCULUS

$\int \frac{du}{u\sqrt{u^2-a^2}} = \frac{1}{a} \operatorname{arcsec} \frac{u}{a}$

$\int e^u du = e^u$; $\int a^u du = \frac{a^u}{\log a}$

$\int u\, dv = uv - \int v\, du$

$\int x e^{ax} dx = e^{ax} = \frac{e^{ax}}{a}(ax - 1)$

$\int e^{ax} \sin mx\, dx = e^{ax} \frac{(a \sin mx - m \cos mx)}{m^2+a^2}$

$\int e^{ax} \cos mx\, dx = e^{ax} \frac{(m \sin mx + a \cos mx)}{m^2+a^2}$

$\int \log x\, dx = x \log x - x$

$\int \frac{dx}{a^2-x^2} = \frac{1}{2a} \log \frac{a+x}{a-x}$

$\int \sqrt{a^2-x^2}\, dx = \frac{1}{2} x \sqrt{a^2-x^2} + \frac{1}{2} a^2 \arcsin \frac{x}{a}$

$\int \sqrt{x^2 \pm a^2}\, dx = \frac{1}{2} x \sqrt{x^2 \pm a^2}$
$\pm \frac{1}{2} a^2 \log\left(x + \sqrt{x^2 \pm a^2}\right)$

$\int (a^2-x^2)^{\frac{3}{2}} dx = \frac{1}{4} x (a^2-x^2)^{\frac{3}{2}} + \frac{3}{8} a^2 x \sqrt{a^2-x^2}$
$+ \frac{3}{8} a^4 \arcsin \frac{x}{a}$

$\int x^2 \sqrt{a^2-x^2}\, dx = -\frac{1}{4} x (a^2-x^2)^{\frac{3}{2}} + \frac{1}{8} a^2 x \sqrt{a^2-x^2}$
$+ \frac{1}{8} a^4 \arcsin \frac{x}{a}$

$\int \sin^2 x\, dx = \frac{1}{2} x - \frac{1}{4} \sin 2x$

$\int \cos^2 x\, dx = \frac{1}{2} x + \frac{1}{4} \sin 2x$

Hyperbolic functions

$\sinh x = \frac{e^x - e^{-x}}{2}$; $\cosh x = \frac{e^x + e^{-x}}{2}$

$d \sinh u = \cosh u\, du$; $d \sinh^{-1} x = \frac{1}{\sqrt{1+x^2}}$

$d \cosh u = \sinh u\, du$

$d \tanh u = \operatorname{sech}^2 u\, du$; $d \cosh^{-1} x = \frac{1}{\sqrt{x^2-1}}$

$\int \sinh x\, dx = \cosh x$

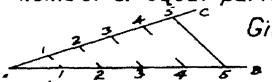
$\int \cosh x\, dx = \sinh x$; $d \tanh x = \frac{1}{1-x^2}$

$\int \tanh x\, dx = \log \cosh x$

Series – see algebra

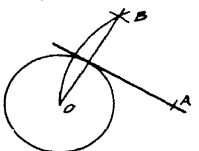
CONSTRUCTIONS

To divide a line into a given number of equal parts.



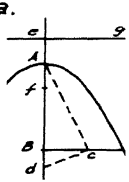
Lay off at any angle line AC and divide into the required number of parts. Draw B5. Lines parallel to B5 divide AB into equal parts.

To draw a tangent from an external point A, to a circle.



With A as center draw arc OB of radius OA. With O as center draw arc of radius OA intersecting arc OB at B. Line OB cuts circle at C, point of tangency.

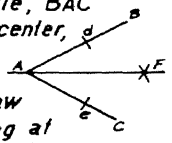
To draw a parabola.



Given ordinate and abscissa, A is vertex, AB ordinate, BL abscissa. Bisect BL at c. Draw cA. Draw cd perpendicular to Ac Lay off Ae & Af equal Bd. Draw eg, the directrix. perpendicular to eAB. All points on curve equidistant from eg and f, the focus.

CONSTRUCTIONS

To bisect an angle, BAC



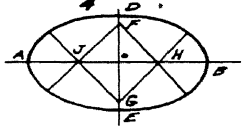
With A as center, draw arc de. With d & e as centers, draw arcs intersecting at F. AF is the bisector.

To draw an ellipse (approx.)

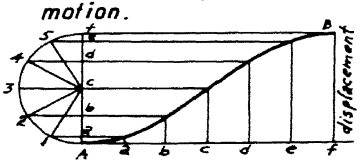
Given axes, minor axis at least two thirds of maj. axis.

$OF \& OG = AB - DE$

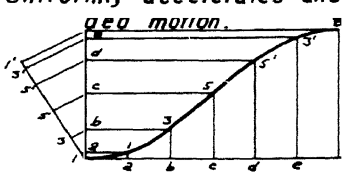
$OH \& OJ = \frac{3}{4} OG$



Sine curve - simple harmonic motion.



Uniformly accelerated and



Lay off Af, divide into parts proportional to 1, 3, 5, 7, 9, etc. See diagram.

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396
N	0	1	2	3	4	5	6	7	8	9

Multiply – add logarithms
Divide – subtract logarithms

Powers – logarithm multiplied by the power
Roots – logarithm divided by the root

Characteristic: number before decimal of log

Numbers	Characteristic
.01 – .09	8.00000 –10
.10 – .19	9.00000 –10

1.00 – 9.99	0.0000
10.0 – 99.9	1.0000
100. – 999.	2.0000

Mantissa: decimal of logarithms (TABLE)

N	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
N	0	1	2	3	4	5	6	7	8	9

CONSTANTS

$\pi = 3.1415926$
$\pi^2 = 9.869604$
$\sqrt{\pi} = 1.77245$
$\frac{1}{\pi} = .318309$
$M = \log_{10} e = .43429$
$e = 2.71828$
$1^\circ = .0175$ radians
$\frac{1}{M} = \log_e 10 = 2.30258$
1 radian $= \frac{\pi}{180} = 57.3^\circ$

Natural (or Naperian) Logarithms of Numbers from .01 to .99

N. B. Since the numbers in this table are less than 1, the logarithms are all *negative* and should be preceded by a minus sign.

N.	0	1	2	3	4	5	6	7	8	9
.0	.....	4.605	3.912	3.507	3.219	2.996	2.813	2.659	2.526	2.408
.1	2.303	2.207	2.120	2.040	1.966	1.897	1.833	1.772	1.715	1.661
.2	1.609	1.561	1.514	1.470	1.427	1.386	1.347	1.309	1.273	1.238
.3	1.204	1.171	1.139	1.109	1.079	1.050	1.022	.994	.968	.942
.4	.916	.892	.868	.844	.821	.799	.777	.755	.734	.713
.5	.693	.673	.654	.635	.616	.598	.580	.562	.545	.528
.6	.511	.494	.478	.462	.446	.431	.416	.400	.386	.371
.7	.357	.342	.329	.315	.301	.288	.274	.261	.248	.236
.8	.223	.211	.198	.186	.174	.163	.151	.139	.128	.117
.9	.105	.094	.083	.073	.062	.051	.041	.030	.020	.010

Natural (or Naperian) Logarithms of Numbers from 1.0 to 9.9

N.	0	1	2	3	4	5	6	7	8	9
1.	.000	.095	.182	.262	.336	.405	.470	.531	.588	.642
2.	.693	.742	.788	.833	.875	.916	.956	.993	1.030	1.065
3.	1.099	1.131	1.163	1.194	1.224	1.253	1.281	1.308	1.335	1.361
4.	1.386	1.411	1.435	1.459	1.482	1.504	1.526	1.548	1.569	1.589
5.	1.609	1.629	1.649	1.668	1.686	1.705	1.723	1.740	1.758	1.775
6	1.792	1.808	1.825	1.841	1.856	1.872	1.887	1.902	1.917	1.932
7.	1.946	1.960	1.974	1.988	2.001	2.015	2.028	2.041	2.054	2.067
8.	2.079	2.092	2.104	2.116	2.128	2.140	2.152	2.163	2.175	2.186
9.	2.197	2.208	2.219	2.230	2.241	2.251	2.262	2.272	2.282	2.293

Natural (or Naperian) Logarithms of Numbers from 10 to 109

N.	0	1	2	3	4	5	6	7	8	9
1	2.303	2.398	2.485	2.565	2.639	2.708	2.773	2.833	2.890	2.944
2	2.996	3.045	3.091	3.135	3.178	3.219	3.258	3.296	3.332	3.367
3	3.401	3.434	3.466	3.497	3.526	3.555	3.584	3.611	3.638	3.664
4	3.689	3.714	3.738	3.761	3.784	3.807	3.829	3.850	3.871	3.892
5	3.912	3.932	3.951	3.970	3.989	4.007	4.025	4.043	4.060	4.078
6	4.094	4.111	4.127	4.143	4.159	4.174	4.190	4.205	4.220	4.234
7	4.248	4.263	4.277	4.290	4.304	4.317	4.331	4.344	4.357	4.369
8	4.382	4.394	4.407	4.419	4.431	4.443	4.454	4.466	4.477	4.489
9	4.500	4.511	4.522	4.533	4.543	4.554	4.564	4.575	4.585	4.595
10	4.605	4.615	4.625	4.635	4.644	4.654	4.663	4.673	4.682	4.691

No.	Square	Cube	Square Root	Cube Root	No.	Square	Cube	Square Root	Cube Root
1	1	1	1.000	1.000	51	2 601	132 651	7.141	3.708
2	4	8	1.414	1.260	52	2 704	140 608	7.211	3.733
3	9	27	1.732	1.442	53	2 809	148 877	7.280	3.756
4	16	64	2.000	1.587	54	2 916	157 464	7.348	3.780
5	25	125	2.236	1.710	55	3 025	166 375	7.416	3.803
6	36	216	2.449	1.817	56	3 136	175 616	7.483	3.826
7	49	343	2.646	1.913	57	3 249	185 193	7.550	3.849
8	64	512	2.828	2.000	58	3 364	195 112	7.616	3.871
9	81	729	3.000	2.080	59	3 481	205 379	7.681	3.893
10	100	1 000	3.162	2.154	60	3 600	216 000	7.746	3.915
11	121	1 331	3.317	2.224	61	3 721	226 981	7.810	3.936
12	144	1 728	3.464	2.289	62	3 844	238 328	7.874	3.958
13	169	2 197	3.606	2.351	63	3 969	250 047	7.937	3.979
14	196	2 744	3.742	2.410	64	4 096	262 144	8.000	4.000
15	225	3 375	3.873	2.466	65	4 225	274 625	8.062	4.021
16	256	4 096	4.000	2.520	66	4 356	287 496	8.124	4.041
17	289	4 913	4.123	2.571	67	4 489	300 763	8.185	4.062
18	324	5 832	4.243	2.621	68	4 624	314 432	8.246	4.082
19	361	6 859	4.359	2.668	69	4 761	328 509	8.307	4.102
20	400	8 000	4.472	2.714	70	4 900	343 000	8.367	4.121
21	441	9 261	4.583	2.759	71	5 041	357 911	8.426	4.141
22	484	10 648	4.690	2.802	72	5 184	373 248	8.485	4.160
23	529	12 167	4.796	2.844	73	5 329	389 017	8.544	4.179
24	576	13 824	4.899	2.884	74	5 476	405 224	8.602	4.198
25	625	15 625	5.000	2.924	75	5 625	421 875	8.660	4.217
26	676	17 576	5.099	2.962	76	5 776	438 976	8.718	4.236
27	729	19 683	5.196	3.000	77	5 929	456 533	8.775	4.254
28	784	21 952	5.292	3.037	78	6 084	474 552	8.832	4.273
29	841	24 389	5.385	3.072	79	6 241	493 039	8.888	4.291
30	900	27 000	5.477	3.107	80	6 400	512 000	8.944	4.309
31	961	29 791	5.568	3.141	81	6 561	531 441	9.000	4.327
32	1 024	32 768	5.657	3.175	82	6 724	551 368	9.055	4.344
33	1 089	35 937	5.745	3.208	83	6 889	571 787	9.110	4.362
34	1 156	39 304	5.831	3.240	84	7 056	592 704	9.165	4.380
35	1 225	42 875	5.916	3.271	85	7 225	614 125	9.220	4.397
36	1 296	46 656	6.000	3.302	86	7 396	636 056	9.274	4.414
37	1 369	50 653	6.083	3.332	87	7 569	658 503	9.327	4.431
38	1 444	54 872	6.164	3.362	88	7 744	681 472	9.381	4.448
39	1 521	59 319	6.245	3.391	89	7 921	704 969	9.434	4.465
40	1 600	64 000	6.325	3.420	90	8 100	729 000	9.487	4.481
41	1 681	68 921	6.403	3.448	91	8 281	753 571	9.539	4.498
42	1 764	74 088	6.481	3.476	92	8 464	778 688	9.592	4.514
43	1 849	79 507	6.557	3.503	93	8 649	804 357	9.644	4.531
44	1 936	85 184	6.633	3.530	94	8 836	830 584	9.695	4.547
45	2 025	91 125	6.708	3.557	95	9 025	857 375	9.747	4.563
46	2 116	97 336	6.782	3.583	96	9 216	884 736	9.798	4.579
47	2 209	103 823	6.856	3.609	97	9 409	912 673	9.849	4.595
48	2 304	110 592	6.928	3.634	98	9 604	941 192	9.899	4.610
49	2 401	117 649	7.000	3.659	99	9 801	970 299	9.950	4.626
50	2 500	125 000	7.071	3.684	100	10 000	1 000 000	10.000	4.642

Angle	L. Sin	L. Cos	L. Tan	Angle	L. Sin	L. Cos	L. Tan
1°	8.2419	9.9999	8.2419	46°	9.8569	9.8418	0.0152
2°	8.5428	9.9997	8.5431	47°	9.8641	9.8338	0.0303
3°	8.7188	9.9994	8.7194	48°	9.8711	9.8255	0.0456
4°	8.8436	9.9989	8.8446	49°	9.8778	9.8169	0.0608
5°	8.9403	9.9983	8.9420	50°	9.8843	9.8081	0.0762
6°	9.0192	9.9976	9.0216	51°	9.8905	9.7989	0.0916
7°	9.0859	9.9968	9.0891	52°	9.8965	9.7893	0.1072
8°	9.1436	9.9958	9.1478	53°	9.9023	9.7795	0.1229
9°	9.1943	9.9946	9.1997	54°	9.9080	9.7692	0.1387
10°	9.2397	9.9934	9.2463	55°	9.9134	9.7586	0.1548
11°	9.2806	9.9919	9.2887	56°	9.9186	9.7476	0.1710
12°	9.3179	9.9904	9.3275	57°	9.9236	9.7361	0.1875
13°	9.3521	9.9887	9.3634	58°	9.9284	9.7242	0.2042
14°	9.3837	9.9869	9.3968	59°	9.9331	9.7118	0.2212
15°	9.4130	9.9849	9.4281	60°	9.9375	9.6990	0.2386
16°	9.4403	9.9828	9.4575	61°	9.9418	9.6856	0.2562
17°	9.4659	9.9806	9.4853	62°	9.9459	9.6716	0.2743
18°	9.4900	9.9782	9.5118	63°	9.9499	9.6570	0.2928
19°	9.5126	9.9757	9.5370	64°	9.9537	9.6418	0.3118
20°	9.5341	9.9730	9.5611	65°	9.9573	9.6259	0.3313
21°	9.5543	9.9702	9.5842	66°	9.9607	9.6093	0.3514
22°	9.5736	9.9672	9.6064	67°	9.9640	9.5919	0.3721
23°	9.5919	9.9640	9.6279	68°	9.9672	9.5736	0.3936
24°	9.6093	9.9607	9.6486	69°	9.9702	9.5543	0.4158
25°	9.6259	9.9573	9.6687	70°	9.9730	9.5341	0.4389
26°	9.6418	9.9537	9.6882	71°	9.9757	9.5126	0.4630
27°	9.6570	9.9499	9.7072	72°	9.9782	9.4900	0.4882
28°	9.6716	9.9459	9.7257	73°	9.9806	9.4659	0.5147
29°	9.6856	9.9418	9.7438	74°	9.9828	9.4403	0.5425
30°	9.6990	9.9375	9.7614	75°	9.9849	9.4130	0.5719
31°	9.7118	9.9331	9.7788	76°	9.9869	9.3837	0.6032
32°	9.7242	9.9284	9.7958	77°	9.9887	9.3521	0.6366
33°	9.7361	9.9236	9.8125	78°	9.9904	9.3179	0.6725
34°	9.7476	9.9186	9.8290	79°	9.9919	9.2806	0.7113
35°	9.7586	9.9134	9.8452	80°	9.9934	9.2397	0.7537
36°	9.7692	9.9080	9.8613	81°	9.9946	9.1943	0.8003
37°	9.7795	9.9023	9.8771	82°	9.9958	9.1436	0.8522
38°	9.7893	9.8965	9.8928	83°	9.9968	9.0859	0.9109
39°	9.7989	9.8905	9.9084	84°	9.9976	9.0192	0.9784
40°	9.8081	9.8843	9.9238	85°	9.9983	8.9403	1.0580
41°	9.8169	9.8778	9.9392	86°	9.9989	8.8436	1.1554
42°	9.8255	9.8711	9.9544	87°	9.9994	8.7188	1.2806
43°	9.8338	9.8641	9.9697	88°	9.9997	8.5428	1.4569
44°	9.8418	9.8569	9.9848	89°	9.9999	8.2419	1.7581
45°	9.8495	9.8495	0.0000	90°	0.0000		

Angle	Sine	Cosine	Tangent	Angle	Sine	Cosine	Tangent
1°	.0175	.9998	.0175	46°	.7193	.6947	1.0355
2°	.0349	.9994	.0349	47°	.7314	.6820	1.0724
3°	.0523	.9986	.0524	48°	.7431	.6691	1.1106
4°	.0698	.9976	.0699	49°	.7547	.6561	1.1504
5°	.0872	.9962	.0875	50°	.7660	.6428	1.1918
6°	.1045	.9945	.1051	51°	.7771	.6293	1.2349
7°	.1219	.9925	.1228	52°	.7880	.6157	1.2799
8°	.1392	.9903	.1405	53°	.7986	.6018	1.3270
9°	.1564	.9877	.1584	54°	.8090	.5878	1.3764
10°	.1736	.9848	.1763	55°	.8192	.5736	1.4281
11°	.1908	.9816	.1944	56°	.8290	.5592	1.4826
12°	.2079	.9781	.2126	57°	.8387	.5446	1.5399
13°	.2250	.9744	.2309	58°	.8480	.5299	1.6003
14°	.2419	.9703	.2493	59°	.8572	.5150	1.6643
15°	.2588	.9659	.2679	60°	.8660	.5000	1.7321
16°	.2756	.9613	.2867	61°	.8746	.4848	1.8040
17°	.2924	.9563	.3057	62°	.8829	.4695	1.8807
18°	.3090	.9511	.3249	63°	.8910	.4540	1.9626
19°	.3256	.9455	.3443	64°	.8988	.4384	2.0503
20°	.3420	.9397	.3640	65°	.9063	.4226	2.1445
21°	.3584	.9336	.3839	66°	.9135	.4067	2.2460
22°	.3746	.9272	.4040	67°	.9205	.3907	2.3559
23°	.3907	.9205	.4245	68°	.9272	.3746	2.4751
24°	.4067	.9135	.4452	69°	.9336	.3584	2.6051
25°	.4226	.9063	.4663	70°	.9397	.3420	2.7475
26°	.4384	.8988	.4877	71°	.9455	.3256	2.9042
27°	.4540	.8910	.5095	72°	.9511	.3090	3.0777
28°	.4695	.8829	.5317	73°	.9563	.2924	3.2709
29°	.4848	.8746	.5543	74°	.9613	.2756	3.4874
30°	.5000	.8660	.5774	75°	.9659	.2588	3.7321
31°	.5150	.8572	.6009	76°	.9703	.2419	4.0108
32°	.5299	.8480	.6249	77°	.9744	.2250	4.3315
33°	.5446	.8387	.6494	78°	.9781	.2079	4.7046
34°	.5592	.8290	.6745	79°	.9816	.1908	5.1446
35°	.5736	.8192	.7002	80°	.9848	.1736	5.6713
36°	.5878	.8090	.7265	81°	.9877	.1564	6.3138
37°	.6018	.7986	.7536	82°	.9903	.1392	7.1154
38°	.6157	.7880	.7813	83°	.9925	.1219	8.1443
39°	.6293	.7771	.8098	84°	.9945	.1045	9.5144
40°	.6428	.7660	.8391	85°	.9962	.0872	11.4301
41°	.6561	.7547	.8693	86°	.9976	.0698	14.3006
42°	.6691	.7431	.9004	87°	.9986	.0523	19.0811
43°	.6820	.7314	.9325	88°	.9994	.0349	28.6363
44°	.6947	.7193	.9657	89°	.9998	.0175	57.2900
45°	.7071	.7071	1.0000	90°	1.0000	.0000	

COMPOUND INTEREST: $(1+r)^n$

n	2%	2½%	3%	3½%	4%	4½%	5%	6%	7%
1	1.0200	1.0250	1.0300	1.0350	1.0400	1.0450	1.0500	1.0600	1.0700
2	1.0404	1.0506	1.0609	1.0712	1.0816	1.0920	1.1025	1.1236	1.1449
3	1.0612	1.0769	1.0927	1.1087	1.1249	1.1412	1.1576	1.1910	1.2250
4	1.0824	1.1038	1.1255	1.1475	1.1699	1.1925	1.2155	1.2625	1.3108
5	1.1041	1.1314	1.1593	1.1877	1.2167	1.2462	1.2763	1.3382	1.4026
6	1.1262	1.1597	1.1941	1.2293	1.2653	1.3023	1.3401	1.4185	1.5007
7	1.1487	1.1887	1.2299	1.2723	1.3159	1.3609	1.4071	1.5036	1.6058
8	1.1717	1.2184	1.2668	1.3168	1.3686	1.4221	1.4775	1.5938	1.7182
9	1.1951	1.2489	1.3048	1.3629	1.4233	1.4861	1.5513	1.6895	1.8385
10	1.2190	1.2801	1.3439	1.4106	1.4802	1.5530	1.6289	1.7908	1.9672
11	1.2434	1.3121	1.3842	1.4600	1.5395	1.6229	1.7103	1.8983	2.1049
12	1.2682	1.3449	1.4258	1.5111	1.6010	1.6959	1.7959	2.0122	2.2522
13	1.2936	1.3785	1.4685	1.5640	1.6651	1.7722	1.8856	2.1329	2.4098
14	1.3195	1.4130	1.5126	1.6187	1.7317	1.8519	1.9799	2.2609	2.5785
15	1.3459	1.4483	1.5580	1.6753	1.8009	1.9353	2.0789	2.3966	2.7590
16	1.3728	1.4845	1.6047	1.7340	1.8730	2.0224	2.1829	2.5404	2.9522
17	1.4002	1.5216	1.6528	1.7947	1.9479	2.1134	2.2920	2.6928	3.1588
18	1.4282	1.5597	1.7024	1.8575	2.0258	2.2085	2.4066	2.8543	3.3799
19	1.4568	1.5987	1.7535	1.9225	2.1068	2.3079	2.5270	3.0256	3.6165
20	1.4859	1.6386	1.8061	1.9898	2.1911	2.4117	2.6533	3.2071	3.8697
21	1.5157	1.6795	1.8603	2.0594	2.2788	2.5202	2.7860	3.3996	4.1406
22	1.5460	1.7216	1.9161	2.1315	2.3699	2.6337	2.9253	3.6035	4.4304
23	1.5769	1.7646	1.9736	2.2061	2.4647	2.7522	3.0715	3.8197	4.7405
24	1.6084	1.8087	2.0328	2.2833	2.5633	2.8760	3.2251	4.0489	5.0724
25	1.6406	1.8539	2.0938	2.3632	2.6658	3.0054	3.3864	4.2919	5.4274
26	1.6734	1.9003	2.1566	2.4460	2.7725	3.1407	3.5557	4.5494	5.8074
27	1.7069	1.9478	2.2213	2.5316	2.8834	3.2820	3.7335	4.8223	6.2139
28	1.7410	1.9965	2.2879	2.6202	2.9987	3.4297	3.9201	5.1117	6.6488
29	1.7758	2.0464	2.3566	2.7119	3.1187	3.5840	4.1161	5.4184	7.1143
30	1.8114	2.0976	2.4273	2.8068	3.2434	3.7453	4.3219	5.7435	7.6123
31	1.8476	2.1500	2.5001	2.9050	3.3731	3.9139	4.5380	6.0881	8.1451
32	1.8845	2.2038	2.5751	3.0067	3.5081	4.0900	4.7649	6.4534	8.7153
33	1.9222	2.2589	2.6523	3.1119	3.6484	4.2740	5.0032	6.8406	9.3253
34	1.9607	2.3153	2.7319	3.2209	3.7943	4.4664	5.2533	7.2510	9.9781
35	1.9999	2.3732	2.8139	3.3336	3.9461	4.6673	5.5160	7.6861	10.6766
36	2.0399	2.4325	2.8983	3.4503	4.1039	4.8774	5.7918	8.1473	11.4239
37	2.0807	2.4933	2.9852	3.5710	4.2681	5.0969	6.0814	8.6361	12.2236
38	2.1223	2.5557	3.0748	3.6960	4.4388	5.3262	6.3855	9.1543	13.0793
39	2.1647	2.6196	3.1670	3.8254	4.6164	5.5659	6.7048	9.7035	13.9948
40	2.2080	2.6851	3.2620	3.9593	4.8010	5.8164	7.0400	10.2857	14.9745
41	2.2522	2.7522	3.3599	4.0978	4.9931	6.0781	7.3920	10.9029	16.0227
42	2.2972	2.8210	3.4607	4.2413	5.1928	6.3516	7.7616	11.5570	17.1443
43	2.3432	2.8915	3.5645	4.3897	5.4005	6.6374	8.1497	12.2505	18.3444
44	2.3901	2.9638	3.6715	4.5433	5.6165	6.9361	8.5572	12.9855	19.6285
45	2.4379	3.0379	3.7816	4.7024	5.8412	7.2482	8.9850	13.7646	21.0025
46	2.4866	3.1139	3.8950	4.8669	6.0748	7.5744	9.4343	14.5905	22.4726
47	2.5363	3.1917	4.0119	5.0373	6.3178	7.9153	9.9060	15.4659	24.0457
48	2.5871	3.2715	4.1323	5.2136	6.5705	8.2715	10.4013	16.3939	25.7289
49	2 6388	3.3533	4.2562	5.3961	6.8333	8.6437	10.9213	17.3775	27.5299
50	2.6916	3.4371	4.3839	5.5849	7.1067	9.0326	11.4674	18.4202	29.4570

PHYSICS

Mechanics
Heat
Light
Sound
Electricity

Tables

UNITS

c.g.s. units given first; f.p.s. given second

Length
- meter, m, scientific unit
- centimeter, cm = .01 meter
- foot, ft, engineering unit
- inch, in = 1/12 foot

Mass & weight
- gram, gm, scientific unit
  - 1 cc. H_2O weighs one gram
- kilogram = 1000 grams
- pound, lb, engin. unit
- ton = 2000 pounds

Time
- second = 1/86,400 of mean solar day = period of one oscillation of 39.16" pendul.

Force
- dyne - force which will give 1 gm mass an acc. of 1 cm/sec.^{2}
- poundal - force which will give 1 lb mass an acc. of 1 ft/sec.^{2}
- Acc. caused by force of gravity = 980 cm/sec.^{2} = 32 ft/sec.^{2}

Work & energy
- erg - work done by force of one dyne moving one cm.
- foot poundal - work done by force of one poundal moving 1 ft.
- joule = 10^7 ergs = work done by a watt in one second.
- foot pound - work done by force of one lb moving 1 ft.

UNITS

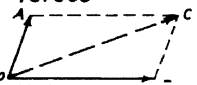
Power - time rate of doing work.
- watt = joule/sec.
- kilowatt, kw, = 1000 watts
- horsepower, HP,
  - = 33,000 ft lbs/min.
  - = 550 ft lbs/sec.
  - = 746 watts

Equivalents
- 1 in. = 2.54 cm ; 1 kg. = 2.205 lbs
- 1 m = 39.37 in ; 1 lb = 454 gms
- (see Physics Tables, page 3c, for complete list.)

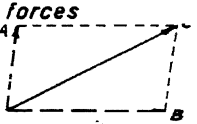
MECHANICS

Statics

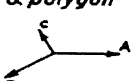
Composition of forces
- Given: A & B
- Resultant C
- obtained by drawing parallelogram



Resolution of forces
- Given C
- Components A & B

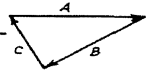


Forces in equilibrium (means no acceleration.
- Sum of components = o
  - $\Sigma F = o$ (usually horiz. & vert.).
  - 3 forces in equil. must meet in a point & polygon must close.
  - Given any 2, i.e. A & C,



MECHANICS

third found by force polygon. Lay off A & C to scale in proper direction. Then C must close polygon.



Moment of a force is torque.

Torque = Fd

For a body in equilibrium the sum of moments or torques = o.

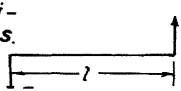
$\Sigma M = o$

F = force in gms. or lbs.
d = perpendicular dist. from line of force to center of rotation.

Couple

Equal and opposite, but non-coincident forces.

$T = Fl$



Solving problems in statics:

Isolate parts & indicated forces & directions if known or unknown.

Resolve components & see that they = o.

Take moments about assumed center of rotation. Choose point that will make least known forces drop out, i.e., thru which these act.

MECHANICS

Dynamics or kinetics

$S = Vt$ — S = distance, cm, ft. V = average velocity in cm/sec, ft/sec t = time in sec

22 ft/sec = 15 mph

$V = at$ — a = acceleration in cm/sec^2, ft/sec^2; a for falling body = g

$V = V_o + at$ — V_o = initial velocity in cm/sec, ft/sec

$S = \frac{1}{2}at^2$; $S = h$ in cm. or ft. for falling body

$S = V_o t + \frac{1}{2}at^2$

$V = \sqrt{2aS}$

Force

$F = ma = \frac{w}{g}a$ — $m = \text{mass} = \frac{w}{g}$; w = weight in gms, lbs.; g = 980; 32.2; a = acc. in cm/sec^2 or ft/sec^2

$M = mV$ — M = momentum in $\frac{\text{gm. cm}}{\text{sec}}$, $\frac{\text{lbs. ft}}{\text{sec}}$

$Ft = M$ — F = force in gm, lb. t = time in sec.

Rotation

$\theta = \frac{\text{arc}}{\text{radius}}$

radian = 57.3°

$\theta = \omega t$ — θ = angular displ. in radians

$\omega = \alpha t$ — ω = angular velocity in rad/sec

$\omega = \omega_o + \alpha t$; ω_o = initial ω

MECHANICS

Dynamics or kinetics

$\omega = \frac{2\pi n}{60}$ α = angular acc. in rad/sec^2

n = r.p.m.

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$V = \omega r$ r = radius of pt. in question in cm. or ft.

$a = \alpha r$

Torque & moment of inertia

$T = I\alpha$ T = torque = Fr or Fd

$r = d$ = perpendicular distance between line of force & center of rot., cm., ft.

$I = \Sigma mr^2$ I = mom. of inertia in gm.cm^2, lb.ft.^{2}

$I = I_o + md^2$ $m = \frac{w}{g} = \frac{\text{wt. in gm, lb}}{980 \text{ or } 32.2}$

I_o = mom. of inertia about center of gravity in gm.cm^2, lb.ft.^{2}

$d = r$ = dist from c. of g. to c. of rotation.

Moments of inertia of some common shapes about axis through c.g.

Solid disc or cyl. - $mr^2/2$
Circular ring - mr^2
Sphere - $2mr^2/5$
Beam (about center of length) - $ml^2/12$
l = length in cm, in.

$I = m\rho^2 = \frac{w}{g}\rho^2$; ρ = radius of gyration

$\rho = \sqrt{I / \frac{w}{g}}$

$C.F. = \frac{mv^2}{r} = m\omega^2 r$ m = mass $\frac{w}{g}$

$C.F. = \frac{wv^2}{gr}$ $C.F.$ = centrifugal force in gm, lb.

$= \frac{w\omega^2 r}{g}$

$a = \frac{v^2}{r}$ r = radius, cm, ft.

a = acc. toward c. of rotation

Periodic motion

$T = \frac{2\pi}{\omega}$ T = period in secs. (complete cycle-to&fro)

$N = \frac{1}{T} = \frac{\omega}{2\pi}$ ω = ang. vel., rad/sec.

N = frequency or no. of vib./sec. or r.p.s.

Simple pendulum

$T = 2\pi\sqrt{\frac{l}{g}}$ T = period of 1 complete vib.

$\frac{T}{T_1} = \frac{\sqrt{l}}{\sqrt{l_1}}$ l = length, cm, ft.

l_1 = length of 2nd

T_1 = period of 2nd

One second = period of a single oscillation of a 39.16" simple pendulum. g = 980 cm/sec^2 = 32.2 ft/sec^2

Friction, work, power, energy

Units - see first column

Friction

$F = fp = \mu p$ F = force req'd to move object in gm, lb.

$f = \mu$ = coefficient of friction .2 is a common value. (see tables)

p = pressure in gm/cm^2, lb/in.^{2}

MECHANICS Dynamics or kinetics

Work

$W = Fs$ — W = work, cm gm, ft lb.; s = distance, cm, ft.

$K.E. = \frac{1}{2} I\omega^2$; I = mom. of inertia, in cm^4, in^4; ω = ang. vel., rad/sec.

Potential Energy

$P.E. = mgh = wh$ — $P.E.$ = pot. energy; w = weight, gm, lb.; h = height, cm, ft.

Kinetic energy

$K.E. = \frac{1}{2} mv^2 = \frac{w}{2g} v^2$ — $K.E.$ = kin. energy; v = vel., cm/sec, ft/sec; g = 980, 32.2

Power

$P = \frac{work}{time}$ — P = power, w, H.P.

watt = joule/sec = volt × amp.

H.P. = 550 ft. lb./sec = 746 watts

Machines & efficiency

$M.A. = \frac{d}{d_1}$ — $M.A.$ = theoretical mech. advant.

$A.M.A. = \frac{F}{F_1}$ — $A.M.A.$ = actual mech. advant.

Lever: $M.A. = \frac{d}{d_1}$ — d = distance F moves; d_1 = dist. F_1 moves; F = opposing force, gm, lb.; F_1 = applied force

Wheel & axle: $M.A. = \frac{R}{r}$ — R = radius wheel; r = radius of axle

Pulley: $M.A.$ = no. of supporting strands

Inclined plane

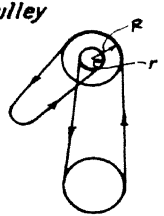
$M.A. = \frac{L}{h}$ — L = lgth. of slope, cm, ft.; h = rise in lgth., cm, ft.

Screw

$M.A. = \frac{2\pi r}{p}$ — r = rad. of lever, cm, ft.; p = pitch of thread = advance in one turn, cm, ft.

Differential pulley

$M.A. = \frac{2R}{R-r}$



Efficiency

$E = \frac{A.M.A.}{M.A.} = \frac{output}{input}$

Elasticity

Stress $\frac{P}{A}$ — P = force, dynes, lb.; A = area, cm^2, $in.^2$

Strain $= \frac{\Delta}{L}$ — L = length, cm, in.; Δ = deformation in cm, in.

$\Delta = \frac{PL}{AE}$ — $E = \frac{stress}{strain}$ = Young's modulus of elast'y; $= 30 \times 10^6$ for steel.

Twist or torsion

$\phi = \frac{M_t \cdot L}{G \cdot I_p}$; ϕ = angle of twist, ra; M_t = twisting moment = Fr.

G = modulus of elas. in shear. G for steel = 12×10^6 #/in^2

L = length, in.

I_p = polar moment of inertia; for shaft, $I_p = \frac{\pi d}{32}$ $in.^4$

FLUID MECHANICS

Hydrostatics

$P = \frac{F}{A}$ F = force, gm, lb. P = pressure, gm/cm², lb/in². A = area, cm², in².

$F = PA$

$P = hd$ h = hgt., cm, ft. d = density, gm/cm³, lb/ft³. For water d = 1, 62.4

density $d = \frac{w}{v}$ w = wgt, gm, lb. v = volume, cm³, ft³

Specific gravity = $\frac{d}{1}$, $\frac{d}{62.4}$

Liquids exert pressure normal to surface.

Mech. adv. of hydraulic press $MA = \frac{A}{a} = \frac{D^2}{d^2}$ A = area large cyl. a = " small ". D = diam. large ". d = " small ".

Pressure of weight of liquid

$P = hdg$, dynes, poundals

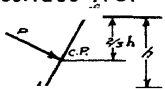
$P = hd$, gm, lb; h = head, cm, ft. d = density gm/cc, lb/ft.

Center of pressure on partially submerged surface AC.

$CP = \frac{2}{3}h$

$P = \frac{2}{3}dh$

$F = \frac{1}{2}dhA$



P = pressure, gm/cm², lb/ft².
h = cm, ft.
A = area sub. surf.

Buoyant force = weight of fluid displaced (Archimedes' princ.)

FLUID MECHANICS

B.F. = $W = dV$; B.F. = buoy. force, gm, lb.
W = weight displ. liquid, gm, lb.
d = density, gm/cm³, lb/ft³. For water, 1, 62.4.
V = volume, cm³, ft³.

Surface tension

For water = 75 dynes/cm apprx.
mercury = 550 dynes/cm approx

Height of liquid in capillary

$h = \frac{2T\cos\alpha}{rdg}$; h = hgt., cm.
T = surf. tens., dynes
r = radius tube, cm
d = dens. of liq.
α = angle liquid meets surface, = 0 for water, = 40° for Hg.

Flow of fluids

$V^2 = 2gh$ V = vel., cm/sec, ft/sec.

$V = \sqrt{2gh}$ g = 980, 32.2
h = head, cm, ft.

$Q = AV$ Q = quantity, cm, ft.
A = area at pt. of V
V = vel., cm/sec, ft/sec.

Bernoulli's theorem (flow in pipes)

Total hd = vel. hd + stat. hd + press.

$h = \frac{V}{2g} + h + \frac{P}{d}$

h = head, cm, ft.
V = vel., cm/sec, ft./sec.
g = 980, 32.2.
P = pressure
d = density

HEAT

Units (do not mix units)

Small or gram calorie = heat required to raise 1 gm H_2O 1°C.

Large calorie = 1000 gm. cals. is common-food heat value, etc.

British thermal unit, BTU = heat required to raise 1 lb. H_2O 1° F.

Mech. equivalents of heat

4.18×10^7 ergs = 4.18 joules = 1 cal.

1 BTU = 778 ft. lb.

Temperature scales

$C = \frac{5}{9}(F - 32°)$

$F = \frac{9}{5}C + 32°$

$A = C + 273°C$

$A = F + 459.4° F$

Expansion

$L = K_L t$ L = change in length; K = coeff. of expansion/deg./unit lgth.; t = temp. change

Conduction

$H = \frac{KAT(t_1 - t_2)}{d}$; H = heat transm'd.; K = a constant depending on material (see p. 3c); d = dist. thru body, thickness; T = time; $(t_1 - t_2)$ = diff. in temp. between sides of body.

Specific heat = s = heat required to change unit mass one degree

HEAT

Calorimetry or heat exchange

$ms\,t = m's't'$ m = mass or weight, gm, lb.; t = temp change, °C, F.; s = spec. heat.; s for water = 1; s for air = .24

Change of state

Heat of fusion = heat required to change 1 gm of substance from solid to liquid with no change in temp. For ice, ht. of fusion = 80 cal/gm. (see page 3c).

Heat of vaporization = heat required to change 1 gm of liquid to vapor with no change in temp. For water, ht. of vap. = 538 cal/gm. (at 760 mm. press).

Gas law & thermodynamics

Gas law (ideal gas)

$PV = wRT$ P = pressure, gm/cm², lb/ft.²; w = weight, gm, lb.; V = volume, cm³, ft.³; T = absolute temp.

R = gas constant; for air = 53.34

$R = \frac{1544}{\text{molec. wt.}}$ for stm. = 85.7

$R = J(c_p - c_v) = 778\ (c_p - c_v)$

c_p = sp. ht. at const. pr., 3.5, .24

c_v = sp. ht. at const. vol., 2.5, .17

$\frac{PV}{T} = \frac{P'V'}{T'}$ (laws of Boyle & Charles)

Adiabatic expansion (insulated — no heat change), $n = K$. $\left[\frac{c_p}{c_v}\right]$

Isothermal expansion (const. temp.), $n = 1$

$P_1 V_1^n = P_2 V_2^n$ $K = \frac{c_p}{c_v}$

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$ n, for air = 1.4

Work = $(P_2 V_2 - P_1 V_1)/1-n$ adiabatic

$W = P_1 V_1 \log_e V_2/V_1$ isothermal or air cycle.

SOUND

Definitions

Pitch - Determined by number of vibrations/sec. Middle C is 256 vibrations/sec.

Intensity - Varies inversely as square of dist. from source.

Beat - Variation in loudness caused by wave interference. No. of beats/sec. = diff. in freq.

Velocity

$V = n\lambda$ — V=vel. of transm., cm/sec., ft/sec.; n=vibr./sec.; λ=wave lgth., cm, ft.

In gas

$V = \sqrt{\frac{Kp}{d}}$ — $K = \frac{\text{sp. ht. const. press}}{\text{sp. ht. const. vol.}}$; K for air = 1.4; p=press., dynes/cm^2; d=density, gm/cm^3

V in air at any temperature

$V = V_o\sqrt{1 + \frac{t}{273}}$; V_o=vel. at 0°C; t=temp °C

V_o = 331.7 cm/sec, 1086 ft/sec.

In any substance

$V = \sqrt{\frac{E}{d}}$ — E=modulus of elast.; d=density; V for H_2O=1450 m/sec

Vibration of strings

$n = \frac{1}{2l}\sqrt{\frac{F}{w}}$ — F=tension, gm, lb.; l=length, cm, ft.; n=vib./sec; w=weight, gm/cm, lb/ft. of l

Vibrating columns

Open: $\lambda = 2L$

Closed: $\lambda = 4L$

λ=wavelength, m, ft.; L=length of column, m, ft.

LIGHT

Intensity

$\frac{I_1}{I_2} = \frac{d_2^2}{d_1^2}$ — I= intensity; d=distance from source

Reflection

$\angle i = \angle r$ — $\angle i$=angle of incidence; $\angle r$ angle of reflection

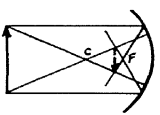
Index of refraction μ

$\mu = \frac{\sin \angle i}{\sin \angle r}$

Light bends toward normal in passing to substance of greater velocity and away when passing to substance of less vel.

Lenses & Mirrors

$\frac{1}{F} = \frac{1}{D_o} + \frac{1}{D_i}$

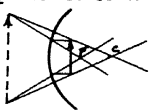


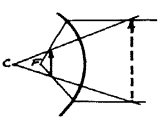
F= focal lgth. or approx. $\frac{1}{2}$ rad. of curv.

D_o=distance of object from lens or mir.

D_i=distance of image from lens or mir.

c (for figures) =center of curvature.





Color

Objects absorb all colors except the color they appear, which they reflect.

Black absorbs all colors.

White reflects all colors.

ELECTRICITY

Units

Charge - Coulomb = ampere × second = 3×10^9 esu.

Current - Ampere, amount of current that will deposit .00118 gm of silver / sec. = 10 emu.

EMF - Volt = difference of potential that will cause one ampere to flow thru resistance of one ohm = $1/300$ esu., 10^8 emu.

Resistance - Ohm = resistance of column of Hg 106.25 cm high, 1mm in area at 0°C.

Capacity - Farad = capacity of condenser raised to 1 volt potential diff. by 1 coulomb charge. Common unit is microfarad = 10^{-6} far.

Inductance - Henry = induc. in which 1 amp change of current/sec induces 1 volt.

Power - Watt = 1 amp × 1 volt.

Electrostatics

$F = \frac{Qq}{d^2}$ — F = mutual force, dynes; Q, q = chgs. on bodies, esu.; d = dist. betw. bodies, cm.

$C = \frac{Q}{V}$ — C = capacitance, farads; Q = charge, coulombs; V = potential diff., volts

$C = \frac{KA}{4\pi t}$ — K = dielectric constant; A = plate area, cm.²; t = plate spacing, cm, in.

K, air = 1, glass = 3

Condensers in parallel

$$C = C_1 + C_2 + C_3 = \frac{Q_1 + Q_2 + Q_3}{V}$$

series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

ELECTRICITY

Magnetism

$\frac{mm'}{d^2}$ — F = mutual force dynes; m, m' = pole strengths; d = dist. betw. poles, cm.

$F = mH$ — H = mag. field inlens, persted

$B = \mu H$ — μ = permeability; air = 1

$\phi = BA$ — ϕ = mag. flux, maxwells; A area, cm.²

Current electricity

$W = QE = IEt$: W = work, watt·secs.; t = time, secs.

Ohm's law $E = IR$ — Q = charge quant., coul.; E = pot. diff., volts; I = current, amps.

Conductor $R = \frac{Kl}{A}$ — K = spec. resist. (tables); R = resistance, ohms; l = length, cm.; A = area, cm.²

Resistances in parallel:

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$

series:

$$R = r_1 + r_2 + r_3$$

Power = $EI = I^2R$, watts (see units)

Heat - $.24\, I^2Rt$ = calories

$I^2Rt/1056$ = BTU

Cells or batteries — n = no. of cells

Series $I = \frac{nE}{R + nr}$; R = ext. resistance; r = internal " .

Par. $I = \frac{E}{R + r/n}$ — E = pot. of 1 cell

Motors & generators

E's in volts

$E = E' + I_a R_a$ — E = applied emf.; E' = counter emf.

applied power = mech. pow. + loss.; I = current, amps.

$E_t I_t = E_a' I_a + I^2R$; R = motor resis.; t, total; a, armature

Alternating current

$I = \frac{E}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}$ — $\omega = 2\pi f$; L = induc., C = capac.; f = freq., cyc/sec.

Power = $EI \cos\theta$ — $\cos\theta$ = pow. factor; θ = angle betw. E & I

Constants

$\pi = 3.14159$ $\sqrt{2} = 1.414$ $\sqrt{3} = 1.732$
1 radian = 57.3° 2π radians = 360°
1 cc. of water at 4°C = 1.000 gram
1 cu.ft. of water at 4°C = 62.4 lb.
1 gal. of water = 8.34 lb.
1 cc. of mercury at 0°C = 13.6 grams
1 cu.ft. of air at 0°C = .0807 lb.
1 atmosphere = 760 mm. or 29.29 in. of Hg.
1 atmosphere = 14.7 lb/in.^{2} or 2116 lb/ft.^{2}
g = accel. of grav. = 980cm/sec^2=32.2ft/sec^2
J = mech. equiv. of heat = 778 ft.lb/Btu.
Mech. equivalent of heat = 4.19 joules/cal.
Electrochemical equivalent = 96,500 coulombs
Avogadro's number = 6.06×10^{23}
Mass of electron = 9.03×10^{-23}
Charge of electron = 4.77×10^{-10}
Vel. of light = 300,000km/sec;186,000mi/sec

EQUIVALENTS, WEIGHTS, AND MEASURES

Conversions - c.g.s. and f.p.s. systems

1 in. = 2.54 cm.	1 m. = 39.37 in.
1 ft. = .3048 m.	1 m. = 3.28 ft.
1 yd. = .9144 m.	1 m. = 1.09 yd.
1 mi. = 1.584 km.	1 km. = .62 mi.
1 oz. = 28.35 g.	1 g. = .035 oz.
1 lb. = 453.6 g.	1 g. = 2.205 lb.
1 qt. = .946 L	1 L. = 1.057 qt.
1 gal. = 3.785 L	1 L. = .264 gal
1 cu.ft. = 28.32 L	1 L. = 61 cu.in.
C = 5/9 (°F - 32)	F = 9/5 °C + 32
1 B.T.U. = 252 cal.	1 cal. = .0039 B.T.U.
1 H.P. = 746 watts	1 kw = 1.34 H.P.
1 ft.lb. = 1.356 joules	1 joule = .738 ft.lb.

English System (f.p.s.)

7000 grains(gr) = 1 pound(lb)
16 ounces(oz) = 1 pound
2000 pounds = 1 ton

12 inches(in) = 1 foot 3 feet = 1 yard
5280 feet or 1760 yards = 1 mile(mi)

1 acre = 43,560 sq.ft. or 4840 sq.yd.
640 acres = 1 sq.mi.

2 pints = 1 quart (qt) 1 gal. = 231 cu.in
4 quarts = 1 gallon (gal) 1 cu.ft. = 7.48 gal

1 H.P. = 550 ft.lb./sec or 33,000 ft.lb/min.

Metric System (c.g.s.)

10 milligrams(mg) : 1 centigram(cg) = .01 g.
100 centigrams : 1 gram(g)
1000 grams : 1 kilogram(kg)

10 millimeters(mm) 1 centimeter(cm) = .01 m.
100 centimeters 1 meter(m)
1000 meters 1 kilometer(km)

1 liter(L) = 1000 cubic centimeters(cc)
1 dyne = gm. cm./sec^2 1 dyne cm. = 1 erg
10^7 ergs = 1 joule 1 joule/sec = 1 watt

ACCELERATION OF GRAVITY AT VARIOUS LATITUDES

at sea level	cm./sec^2	ft./sec^2
0°	977.99	32.086
30°	979.30	32.129
40°	980.15	32.157
45°	980.60	32.172
50°	981.05	32.187
60°	981.91	32.215
90°	983.21	32.258

SPECIFIC GRAVITIES AND DENSITIES

Density in grams/cc. = the specific gravity
Density in lbs/cu.ft. = 62.4 x spec. grav.

Solid	Sp.Gr.	Solid	Sp.Gr.
Aluminum	2.7	Lead	11.3
Brass	8.5	Masonry	1.9 - 2.5
Copper	8.9	Nickel	8.8
Cork	.24	Platinum	21.5
Glass, common	2.6	Salt (NaCl)	2.2
Ice	.92	Wood, pine	.5
Iron	7.2 - 7.8	Wood, oak	.8
Liquid		Liquid	
Alcohol	.79	Mercury	13.596
Ether	.72	Milk	1.03
Gasolene	.74	Oils	.8 - .92
Glycerin	1.26	Water, sea	1.03

Gas - Density in gms/cc at 0°C, 760 mm.
Sp.Gr. referred to air = Den./.00129

Air	.00129	Hydrogen	.00009
Ammonia	.00077	Nitrogen	.00125
CO_2	.00198	Oxygen	.00143
Helium	.00018	Steam(100°C)	.000598

MODULI OF ELASTICITY

In dynes/sq.cm (Times 1.45 x 10^{-5} gives lbs./sq.in.)

	Bulk (k)	Rigidity (n or G)	(Young's) Stretch (M or E)
Aluminum	7.4×10^{11}	2.6×10^{11}	7.0×10^{11}
Brass	10.6x "	3.5x "	9.5x "
Copper	13.1x "	4.5x "	12.3x "
Glass	4.5x "	3. x "	7. x "
Iron	15. x "	7.5x "	19.5x "
Steel	17. x "	8. x "	20. x "

SURFACE TENSION

In dynes/cm. at temperatures indicated

Acetone (17°C)	23	Oil, olive (20°C)	32
Alcohol (20°C)	22	Petroleum (25°C)	26
Ether (20°C)	16.5	Water (15°C)	73
Mercury (20°C)	465	Water (100°C)	58

COEFFICIENTS OF EXPANSION

Per unit length. Expan. per °F =5/9 ex.per C

Linear expansion per degree centigrade

Aluminum	22.0 x 10^{-6}	Iron	11. x 10^{-6}
Brass	18.6 x	Platinum	8.9 x "
Concrete	12. x	Quartz	.5 x "
Copper	16.8 x	Silver	19.0 x "
Glass, soda	8.9 x	Wood, white pine	
Glass, pyrex	3. x	along gr.	5 x "
Invar	0.9 x	acr. grain	34 x

Cubical expansion per degree centigrade

Alcohol	.00112	Mercury	.00018
Ether	.00165	Water, Av.	.00019

Expansion of Gases per degree centigrade

	Const. Pr.	Const. Vol.
Air	.0036610	.0036625
Ammonia	.003800	.003770
Carbon dioxide	.003723	.003714
Hydrogen	.003660	.003664
Nitrogen	.003671	.003672
Oxygen	.003668	.003674
Sulphur dioxide	.003903	.003845

SPECIFIC HEATS

Aluminum	.217	Silver	.056
Copper	.092	Wood, pine	.42
Glass	.185	Alcohol	.58
Ice	.510	Mercury	.033
Iron	.105	Oil, mineral	.52
Lead	.031	Water	1.000

Gases	Const. Press.	Const. Vol.
Air	.242	.173
Ammonia	.523	.399
Carbon dioxide	.200	.154
Hydrogen	3.40	2.41
Oxygen	.218	.156
Steam (100°C)	.48	.34

MELTING AND BOILING POINTS; HEAT OF FUSION

At atmos. press	M.P. °C	B.P. °C	Cal/gram
Aluminum	658	1800	94
Copper	1083	2310	41
Ice	0	100	80
Iron	1530	2450	49
Lead	327	1525	5.5
Platinum	1755	3910	27
Silver	961	1955	21
Tin	232	-	14
Zinc	419	-	23

Also heat of vaporization

	M.P.	B.P.	Ht.F	Ht. Vap
Alcohol	-130	78.3	-	202
Ammonia	-76	-33.5	108	341
Ether	-	34.5	-	90
Mercury	-39	357.	3	68
Water	0	100.	80	537

CRITICAL	TEMP.	PRESS.		°C	Atmos.
Air	-140	39	Hydro.	-234	20
Ammonia	130	115	Oxygen	-118	50
CO_2	31	73	SO_2	155	79
Ether	197	36	Water	365	195

VELOCITIES OF SOUND

at 0°C in m./sec or ft./sec.

Air	331.5	1088
Carbon dioxide	258.0	846
Glass	5500	18100
Granite	3950	12960
Hydrogen	1270	4160
Iron	5100	16700
Water	1450	4760
Wood	4100	13450

INDICES OF REFRACTION

For yellow or sodium light, 5890 A.

Diamond	2.42	Alcohol	1.36
Glass, flint	1.65	Petroleum	1.44
Glass, crown	1.52	Water	1.33
Ice	1.31	Air	1.00029

ELECTROMAGNETIC WAVE LENGTHS

Common unit, Angstrom (A) = 10^{-8}cm.

Radio waves	100,000 meters - .03 cm.
Ultra red (heat)	.03 cm. - .000078 cm.
Red	.000078 cm. - .000063 cm.
Orange	.000063 cm. - .000060 cm.
Yellow	.000060 cm. - .000056 cm.
Green	.000056 cm. - .000049 cm.
Blue	.000049 cm. - .000044 cm.
Violet	.000044 cm. - .000038 cm.
Ultra violet	.000038 cm. - .0000001 cm.
X-rays	.00000100 cm. - .000000001 cm.
Gamma rays	.00000010 cm - .0000000001 cm

SPECIFIC RESISTANCES AND TEMP. COEFFICIENTS

	Resist. of cm3 in ohms	Increase/°C
Carbon	.004	-.0005
Copper	1.69×10^{-6}	.0039
Iron	9.90×10^{-6}	.0050
Mercury	$95. \times 10^{-6}$	.0009
Silver	1.55×10^{-6}	.0038
Tungsten	5.6×10^{-6}	.0051
Paraffin	$3. \times 10^{18}$	
Glass	$9. \times 10^{18}$	

DIELECTRIC CONSTANTS, K

Air	1.0006	Paraffin	2
Glass	6 - 8	Quartz	4.5
Hard rubber	2.5	Alcohol	26
Mica	6	Petroleum	3
Oiled paper	2	water	81

COEFFICIENT OF FRICTION

Wood on wood	.25 -.5	Wood on stone	.35 - .45
Metal on wood	.2 -.5	Iron on stone	.3 - .5
Metal on metal	.15 -.3		
Smooth surfaces, greased	.03 -.08		
Masonry on clay	.3 -.5		
Earth on earth	.25 - 1.0		

THERMAL CONDUCTIVITY

Calories conducted/cc./sec. for 1°C diff.

Aluminum	.48	Platinum	.17
Concrete	.0022	Silver	1.01
Copper	.92	Wood, pine	.0004
Glass	.0025	Alcohol	.00046
Hair felt	.0001	Mercury	.0197
Iron	.15	Petroleum	.00035
Lead	.08	Water	.0014
Rubber	.0005	Air	.00006

COEFFICIENTS OF ABSORPTION

Open window	1.00	Plaster on tile	.025
Compact audience	.96	Brick	.025
Hair felt, 1 in.	.58	Glass	.027
Carpets	.18	per object	
Wood sheathing	.06	A person	.44
Plaster on lath	.034	A wooden seat	.C03
		Upholstered "	.30

ELECTROCHEMICAL EQUIVALENTS

Grams per coulomb. Eq. Wt. = 96,500 Coulombs

Copper	.0003295	Tin	.0003084
Hydrogen	.00001045	Zinc	.0003387
Mercury	.0010394		
Nickel	.0003041	Chlorine	.0003671
Silver	.0011183	Oxygen	.0000828

CHEMISTRY

Definitions
Theory
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DEFINITIONS
(ALSO SEE THEORY)

ACID-COMPOUND CONTAINING HYDROGEN COMBINED WITH EITHER A SINGLE ATOM OF A NON-METAL OR WITH A RADICAL COMPOSED OF NON-METALLIC ATOMS. SUBSTANCES WHICH WHEN PLACED IN WATER SOLUTION DISSOCIATE TO PRODUCE HYDROGEN IONS. THE HYDROGEN MAY BE DISPLACED BY A METAL TO FORM A SALT. ACIDS TASTE SOUR, TURN BLUE LITMUS RED, TURN PHENOLPHTHALEIN COLORLESS, NEUTRALIZE A BASE, ARE ELECTROLYTES. IMP. ACIDS: HCL, H_2SO_4, & HNO_3. ORG. ACIDS-SEE ORG. CHEM.

ALCOHOL-COMPOUND IN WHICH AN ATOM OF HYDROGEN IN A HYDROCARBON IS REPLACED BY THE RADICAL OH. AN ALCOHOL IS AN ORGANIC BASE. EX. ETHYL-C_2H_5OH. GRAIN OR DENATURED METHYL-CH_3OH, WOOD, POISONOUS. SEE ORGANIC CHEMISTRY.

ALLOTROPIC-AN ELEMENT IS ALLOTROPIC IF IT APPEARS IN TWO OR MORE FORMS IN THE SAME PHYSICAL STATE. EACH CHARACTERIZED BY DIFFERENT PROPERTIES. I.E. OXYGEN & OZONE, OR RED & WHITE PHOSPHORUS.

ANHYDRIDE-OXIDE WHICH REACTS WITH WATER TO FORM AN ACID OR BASE.

AQUA REGIA-MIXTURE OF HYDROCHLORIC AND NITRIC ACIDS.

ATOMIC WEIGHT-NUMBER THAT EXPRESSES HOW MANY TIMES AN ATOM IS AS HEAVY AS THE HYDROGEN ATOM. THE RELATIVE WEIGHTS OF ATOMS ON THE BASIS OF OXYGEN EQUAL TO 16.

BASE-COMPOUND CONTAINING A METAL OR POSITIVE RADICAL COMBINED WITH ONE OR MORE HYDROXYL (OH) RADICALS. SUBSTANCES WHICH IN WATER SOLUTION DISSOCIATE TO PRODUCE OH IONS. THE OH RADICAL MAY BE DISPLACED BY A NON-METAL OR NEGATIVE RADICAL TO FORM A SALT. BASES TASTE BITTER, FEEL SLIPPERY, TURN RED LITMUS BLUE, READILY TURN PHENOLPHTHALEIN RED, ARE ELECTROLYTES. IMPORTANT BASES: NAOH, NH_4OH, $CA(OH)_2$. ALKALIES ARE VERY SOLUBLE BASES.

DEFINITIONS

CATALYTIC AGENTS-SUBSTANCES WHICH BY THEIR PRESENCE AFFECT THE SPEED OF A REACTION, BUT UNDERGO NO CHANGE THEMSELVES.

COMPOUNDS-SUBSTANCES WHICH CAN BE DECOMPOSED BY ORDINARY CHEMICAL MEANS INTO SIMPLER SUBSTANCES OR ELEMENTS. DENOTED BY FORMULAS WHICH REPRESENT THEIR MOLECULAR WEIGHT, AND ALSO GIVE THE ELEMENTS MAKING UP THE COMPOUND, AND THEIR PROPORTIONS BY WEIGHT.

ELECTROLYSIS-DECOMPOSITION OF A COMPOUND OR ELECTROLYTE (SUBSTANCE WHICH IN SOLUTION CONDUCTS ELECTRICITY) BY USE OF AN ELECTRIC CURRENT.

ELECTROMOTIVE SERIES-ARRANGEMENT OF METALS IN ORDER OF ACTIVITY GIVES A SERIES SUCH THAT A GIVEN METAL IN IT WILL REPLACE FROM A SALT SOLUTION ALL METALS THAT FOLLOW IT, AND BE REPLACED BY ALL THAT PRECEDE IT. ACTIVITY DECREASES FROM TOP TO BOTTOM.

ELEMENT-A MATERIAL OR SUBSTANCE WHICH CANNOT BY ANY ORDINARY CHEMICAL MEANS BE DECOMPOSED INTO SIMPLER SUBSTANCES. DENOTED BY SYMBOLS WHICH REPRESENT ATOMIC WEIGHTS.

EQUIVALENT WEIGHT-WEIGHT OF ELEMENT DISPLACING ONE ATOMIC WEIGHT OF HYDROGEN OR COMBINING WITH ONE ATOMIC WEIGHT OF ANY UNIVALENT ELEMENT. EQUAL TO THE ATOMIC WEIGHT DIVIDED BY THE VALENCE.

GRAM ATOMIC WEIGHT-WEIGHT IN GRAMS EQUAL TO ATOMIC WEIGHT.

GRAM MOLECULAR VOLUME - G.M.V.- EQUALS 22.4 LITERS. VOLUME OF 32 GRAMS OF OXYGEN AT STANDARD CONDITIONS. G.M.V. OF ANY GAS HAS A WEIGHT EQUAL TO THAT OF ITS MOLECULAR WEIGHT.

GRAM MOLECULAR WEIGHT-WEIGHT IN GRAMS EQUAL TO MOLECULAR WEIGHT.

DEFINITIONS

HYDRATES-Solid crystaline compounds containing water combined in definite proportions and with specific physical properties differing from the Anhydrous compound-the hydrate less the water of hydration or crystalization. Ex. copper sulphate; blue crystals, $CuSO_4 5H_2O$. anhydrous white powder. $CuSO_4$. Deliquesence-spontaneous gain of moisture from surrounding atmosphere. Example, calcium chloride which is used to dry gases. Efflorescence-spontaneous loss of water of hydration.

IONS-Electrically charged atoms or groups of atoms. They constitute the molecules of a dissolved acid, base, or salt. Positive ions or cations move toward the negative electrode or cathode. Negative ions or anions move toward the positive electrode or anode. The charge of an ion equals its valence.

ISOTOPES-Atoms with the same atomic number, but different weight, and almost identical chemically.

METALS-Elements with positive valence. Oxides react to form bases Usually heavier than water, conduct electricity, crystaline, opaque and ductile. No absolute distinction from a non-metal.

MOLE-The weight of a quantity of a substance in grams equal to its molecular weight.

MOLECULAR WEIGHT-Number that expresses the weight of a molecule as compared with the weight of the oxygen molecule, taken as 32. See computations.

NON-METALS-Elements with negative valence. The oxides react to form acids. No absolute definition.

DEFINITIONS

OXIDATION-Process by which a substance loses electrons. Combination of oxygen with a substance, commonest form. Reduction is the reverse. Combustion is oxidation so rapid that light and noticeable heat are given off.

OXIDE-Compound of oxygen and another element.

PRECIPITATE-Insoluble product formed by the interaction of substances in solution.

REDUCTION-Opposite of oxidation. Addition of electrons to a substance. Removal of oxygen from a substance, commonest form. Reducing agent is the substance removing the oxygen, commonly carbon, the most important.

SALTS-Compounds made by the union of the positive ion of a base and the negative ion of an acid. Most are strong electrolytes. May be neutral or normal, basic, or acidic. Common salt is NaCl. Neutralization occurs when an acid and a base are mixed. Water and a salt are formed and the acidic and basic properties are reduced or nullified.

STANDARD CONDITIONS-
Temperature - 0°C or 32°F
Pressure - 760mm of mercury or 14.7 lbs. per sq. in.

SUBLIMATION-Changing to a gas from a solid or vice versa without liquefying. Example, iodine.

VALENCE-Number of atoms of hydrogen or chlorine which one atom of an element can combine with or displace. The whole number which multiplied by the equivalent weight gives the atomic weight. I.E. equivalent weight of oxygen is 8, its valence is 2, gives its atomic weight, 16. When two elements unite to form more than one compound, their valences vary.

THEORY

ATOM-SMALLEST UNIT QUANTITY OF AN ELEMENT THAT IS CAPABLE OF ENTERING INTO CHEMICAL COMBINATION

MOLECULE-SMALLEST PARTICLE OF A SUBSTANCE WHICH HAS ALL THE PROPERTIES OF THE SUBSTANCE. COMPOSED OF ATOMS AND GROUPS OF ATOMS ACTING AS UNITS.

ATOMIC THEORY OF MATTER

ALL ELEMENTS COMPOSED OF MINUTE PARTICLES CALLED ATOMS.

ATOMS OF THE SAME ELEMENT HAVE THE SAME WEIGHT, WHICH DIFFERS FROM THE WEIGHTS OF ATOMS OF ALL OTHER ELEMENTS.

ATOMS ALWAYS COMBINE AND SEPARATE AS WHOLES TO FORM MOLECULES OF SUBSTANCES.

ATOMIC STRUCTURE

ATOMS CONSIST OF A NUCLEUS COMPOSED OF PROTONS, NEUTRONS, POSITRONS, AND ELECTRONS, SURROUNDED BY ELECTRON CLOUDS. THE POSITIVE CHARGES EQUAL THE TOTAL NEGATIVE CHARGES.

PROTONS AND NEUTRONS, MAKE UP ALMOST ALL THE MASS, AND DETERMINE THE ATOMIC WEIGHT.

ELECTRONS AND POSITRONS, NEGATIVE AND POSITIVE CHARGES RESPECTFULLY, MAKE UP PRACTICALLY ALL THE CHARGE. THE ELECTRONS OUTSIDE THE NUCLEUS EQUAL THE ATOMIC NUMBER AND DETERMINE THE CHEMICAL PROPERTIES OF THE ELEMENT. ONLY A CERTAIN NUMBER OF ELECTRONS CAN BE HELD IN THE SUCCESSIVE SHELLS OF ELECTRONS SURROUNDING THE NUCLEUS. THE NUMBER OF ELECTRONS THAT CAN BE HELD IN THE FIRST SHELL IS 2; IN SECOND, 8; IN THIRD, 18; IN FOURTH, 32; AND SO FORTH.

ELECTROMOTIVE CHEMISTRY

ELECTRIC CURRENT IS THE FLOW OF ELECTRONS. QUANTITY OF ELECTRICITY MEASURED IN COULOMBS. ELECTROMOTIVE FORCE OR POTENTIAL DIFFERENCE IS MEASURED IN VOLTS. ENERGY IN JOULES EQUALS COULOMBS TIMES VOLTS. AN AMPERE IS A COULOMB PER SECOND. AMPERES TIMES VOLTS EQUALS JOULES PER SECOND OR WATTS.

THEORY

IONIZATION - DISSOCIATION OF ELECTROLYTES INTO CHARGED ATOMS OR GROUPS OF ATOMS. POSITIVE IONS OR CATIONS MOVE TOWARD NEGATIVE ELECTRODE OR CATHODE. NEGATIVE IONS OR ANIONS MOVE TOWARD THE POSITIVE ELECTRODE OR ANODE.

ELECTROLYTES - SUBSTANCES WHICH IONIZE. COMPOUNDS WHICH IN SOLUTION CONDUCT ELECTRICITY AS ACIDS, BASES, AND SALTS.

ELECTROLYSIS - DECOMPOSITION OF AN ELECTROLYTE BY AN ELECTRIC CURRENT. SPEED DEPENDENT UPON CONCENTRATION OF ELECTROLYTE AND THE QUANTITY OF CURRENT.

ELECTROCHEMICAL EQUIVALENT - THE MASS PER COULOMB LIBERATED BY ELECTROLYSIS. THE EQUIVALENT WEIGHT OF AN ELEMENT IS LIBERATED BY 96,500 COULOMBS.

KINETIC MOLECULAR THEORY AND GASES

SUBSTANCES ARE COMPOSED OF MOLECULES IN RAPID MOTION.

MOLECULES OF SOLIDS COHERE SO RIGIDLY THEY MAINTAIN THE SHAPE OF THEIR OBJECT. MOLECULES OF LIQUIDS COHERE TOGETHER FOR THE MOST PART, BUT LESS RIGIDLY THAN IN SOLIDS. MOLECULES OF GASES DO NOT COHERE TOGETHER AND FILL SPACE UNTIL RESTRICTED.

LOWERING TEMPERATURE DECREASES ACTIVITY TILL AT ABSOLUTE ZERO (-273°C) THE MOLECULES ARE AT REST. RAISING TEMPERATURE ACCELERATES MOTION CAUSING SOLIDS TO BECOME LIQUIDS, AND LIQUIDS GASES.

GASES - PRESSURE OF A GAS IS THE FORCE OF THE MOLECULES HITTING SURFACE AND REBOUNDING WITH THE SAME AVERAGE VELOCITY. THE PRESSURE OF A GAS INCREASES DIRECTLY AS THE ABSOLUTE TEMPERATURE.

COMPRESSIBILITY IS DUE TO THE GREAT SPACE BETWEEN MOLECULES. VOLUME DECREASES INVERSELY AS THE PRESSURE.

DIFFUSIBILITY IS DUE TO THE MOTION OF THE MOLECULES.(SCATTER)

PERMEABILITY IS DUE TO THE SPACE BETWEEN MOLECULES. (MIXING)

CRITICAL TEMPERATURE AND PRESSURE - HIGHEST TEMPERATURE AT WHICH A GAS CAN BE LIQUEFIED AND THE PRESSURE REQUIRED TO LIQUIFY AT THIS CRITICAL TEMPERATURE.

THEORY

PERIODIC SYSTEM - See periodic chart. - Properties of elements are periodic functions of their atomic weight. Families have similar properties which vary progressively. Position determined by period, group, family, atomic weight, and fixed by atomic no.

Atomic number represents free positive charges in the nucleus of atom or the exterior electrons.

Line across chart roughly divides electro-positive and negative elements. The farther above or below the line the more negative or positive acting the element. Except group 0 & trans. ele.

Weaknesses; a few unsatisfactory placements, over emphasis on certain valences, no relation to the electromotive series.

RADIOACTIVITY - Action by which elements give off large amounts of energy while undergoing spontaneous disintergration.

Uranium decomposes forming a series of products including radium and finally lead.

Radium decomposes giving off helium, radon, and the first three types of rays following.

Alpha rays-Positive charged helium atoms, fairly penetrating.

Beta rays-Negative charges or stream of electrons. More penetrating than alpha rays.

Gamma rays-not affected by magnetic field. Very short wave lenth, high velocity, and very penetrating.

X-Rays-Similar to gamma rays. Produced by cathode ray (beta) striking a metal plate. Radio, light, and x-rays are all similar electro-magnetic vibrations.

LIQUID MIXTURES AND SOLUTIONS

Emulsion-Mixture of two mutually insoluble liquids. Cannot be separated by filtering. Exam. milk, fats in water, etc.

Suspension-Mixture of a liquid and an insoluble solid. Not a homogeneous or intimate mixture. Appears cloudy, particles eventually settle out, and are filterable. Exam. muddy water.

THEORY

Colloidal Suspension-Intermediate between a solution and a suspension. Finely dispersed particles not visible, filterable, or as finely dispersed as in a solution. Appears to be a solution but does not have the characteristic properties. Exam. water containing gelatine, soap, or starch.

Solution-Body of homogeneous character, the composition of which may be varied continuously within certain limits. No settling, clear, extremely minute subdivision down to molecular magnitudes. Cannot be separated by filtering.

Solute, the substance dissolved.

Solvent, liquid into which the solute is dissolved.

Concentration-relative amounts of substances in solutions.

Saturated solution-one in which no more solute will dissolve at a given temperature and pressure, or which with an excess of solute is found to be in equilibrium.

Supersaturated solution-one containing more solute than a saturated solution, and the recrystalization being delayed.

Molar solution-Mole dissolved in enough solvent to make a liter of solution. (not added to 1 liter)

Normal solution-Equivalent weight dissolved in enough solvent to make one liter of solution. (not added to 1 liter) Are chemically equivalent solutions. Decinormal is 1/10 normal, (.1 N).

Solubility product-Value of the product of the concentrations of the ions in a saturated solution. If product of the molecular concentrations of two solutions is less than sol. prod. no precipitation, if equal or greater than sol. prod. then precipitation.

Properties of solutions-Depend upon concentration, temperature, and solubility. Boiling point increased, freezing point and vapor pressure of solvents reduced.

See electromotive chemistry and solubility tables.

LAWS

AVOGADRO'S (HYPOTHESIS) - MOLECULES IN A GAS
EQUAL VOLUMES OF DIFFERENT GASES CONTAIN EQUAL NUMBERS OF MOLECULES AT SAME TEMPERATURE AND PRESSURE. G.M.V. IS STD. UNIT.

BOYLE'S - PRESSURE OF GASES
VOLUME OF A GAS VARIES INVERSELY AS THE PRESSURE, IF THE TEMPERATURE REMAINS CONSTANT. EXAM. DOUBLE PRESSURE AND HALVE VOLUME.

CHARLES' - TEMPERATURE OF GASES
VOLUME OF A GAS AT CONSTANT PRESSURE IS DIRECTLY PROPORTIONAL TO ITS ABSOLUTE TEMPERATURE. SEE GAS COMPUTATIONS.

COMBINING WEIGHTS OR PROPORTIONS
FOR EACH ELEMENT A NUMBER EXISTS (ATOMIC WEIGHT) WHICH EITHER BY ITSELF OR MULTIPLIED BY A SMALL INTEGER REPRESENTS THE PROPORTIONATE WEIGHT BY WHICH THAT ELEMENT ENTERS INTO CHEMICAL COMBINATION.

CONSERVATION OF MASS
MATTER CAN NEITHER BE MADE NOR DESTROYED AND IN A CHEMICAL CHANGE TOTAL MASSES OF COMPONENTS EQUAL COMBINED MASSES OF PRODUCTS.

DALTON'S - MIXED GASES
PRESSURE EXERCISED BY EACH COMPONENT OF A GASEOUS MIXTURE IS PROPORTIONAL TO ITS CONCENTRATION IN THE MIXTURE AND THE TOTAL PRESSURE IS EQUAL TO THE SUM OF THE PARTIAL PRESSURES. EXAM. OXYGEN IN THE AIR ACTS AS IF ALONE BUT AT A PRESSURE 1/5 THAT OF THE AIR.

DEFINITE OR CONSTANT PROPORTIONS
IN A COMPOUND, FORMED OR DECOMPOSED, THE PROPORTIONS BY WEIGHT OF THE CONSTITUENT ELEMENTS ARE ALWAYS THE SAME. A CHEMICAL COMPOUND CONTAINS ITS CONSTITUENTS IN UNVARYING PROPORTIONS. (REFERS TO A PARTICULAR COMPOUND) THUS 58.5 GRAMS OF NaCl WILL ALWAYS CONTAIN 23 GRAMS OF Na AND 35.5 GRAMS OF Cl.

LAWS

DULONG AND PETIT'S - SPECIFIC HEAT
THE SPECIFIC HEAT OF A SOLID SUBSTANCE MULTIPLIED BY ITS ATOMIC WEIGHT IS APPROXIMATELY 6.4. A FEW EXCEPTIONS, NOTABLY Si & C.

FARADAY'S - ELECTROLYSIS
EQUAL QUANTITIES OF ELECTRICITY DISCHARGE EQUIVALENT QUANTITIES OF IONS I.E. LIBERATE FROM SOLUTIONS OF THEIR COMPOUNDS WEIGHTS OF THE ELEMENTS PROPORTIONAL TO THEIR EQUIVALENT WEIGHTS. 96,500 COULOMBS SET FREE ONE EQUIVALENT WEIGHT OF AN ELEMENT.

GAY-LUSSAC'S - COMBINING VOLUMES OF GASES
VOLUMES OF GASES USED AND GENERATED IN A CHEMICAL CHANGE CAN BE REPRESENTED BY THE RATIO OF SMALL WHOLE NUMBERS. TEMPERATURE AND PRESSURE BEING CONSTANT. EX. H(2 VOL) + O(1 VOL) = STEAM(2 VOL).

GRAHAM'S - DIFFUSION OF GASES
SPEEDS OF DIFFUSION OF GASES ARE INVERSELY PROPORTIONAL TO THE SQUARE ROOTS OF THEIR DENSITIES. HYDROGEN DIFFUSES FOUR TIMES AS FAST AS OXYGEN

HENRY'S - SOLUBILITY OF GASES
THE SOLUBILITY OF A GIVEN GAS (IF NOT TOO SOLUBLE) VARIES DIRECTLY WITH THE PRESSURE. THUS ONE VOLUME OF WATER DISSOLVES THREE VOLUMES OF CARBON DIOXIDE AT THREE ATMOSHERES AND ONLY ONE VOLUME AT ONE ATMOSPHERE.

MOLECULAR CONCENTRATION
THE SPEED OF CHEMICAL ACTION IS PROPORTIONAL TO THE PRODUCT OF THE MOLECULAR CONCENTRATIONS OF THE REACTING SUBSTANCES.

MULTIPLE PROPORTIONS
WHEN AN ELEMENT COMBINES WITH ANOTHER ELEMENT TO FORM MORE THAN ONE COMPOUND, THE DIFFERENT WEIGHTS OF THE ELEMENT WHICH COMBINE WITH A FIXED WEIGHT OF THE OTHER ELEMENT ARE ALWAYS IN A RATIO OF SMALL WHOLE NUMBERS. (A SPECIAL CASE OF COMBINING WEIGHTS.)

CALCULATIONS

WRITING FORMULAS

WRITE SYMBOLS OF ELEMENTS OR RADICALS AND INDICATE VALENCES.
DIVIDE THE LEAST COMMON MULTIBLE (L.C.M.) OF THE VALENCES BY THE VALENCE OF THE ELEMENT OR RADICAL, THE QUOTIENT IS THE NUMBER OF ATOMS OR RADICALS.
EXAMPLES:
CALCIUM HYDROXIDE - $Ca^{++}OH^{-}$; L.C.M. IS 2, THE FORMULA $Ca(OH)_2$

FERRIC OXIDE - $Fe^{+++}O^{--}$; L.C.M. IS 6, THE FORMULA Fe_2O_3

MOLECULAR WEIGHT - TOTAL OF THE ATOMIC WEIGHTS

		EXAMPLE Fe_2O_3
Fe	2 x 56	112
O	3 x 16	48
MOLE. WT.		160

PERCENTAGE COMPOSITION - EQUALS ATOMIC WEIGHTS OF THE ELEMENTS DIVIDED BY THE MOLECULAR WEIGHT OF THE SUBSTANCE, TIMES 100.

$$\%\ Fe = \frac{2 \times 56}{160} \times 100 = 70$$

$$\%\ O = \frac{3 \times 16}{160} \times 100 \quad 30$$

WRITING AND BALANCING EQUATIONS

EXAMPLE: IRON ORE (Fe_2O_3) REDUCED WITH COKE (C).
WRITE EQUATION-(MUST KNOW THE REACTION, A CORRECTLY BALANCED EQUATION IS NOT NECESSARILY RIGHT)

$$Fe_2O_3 + C \rightarrow Fe + CO$$

BALANCE EQUATION-NUMBER OF ATOMS OF EACH ELEMENT ON EACH SIDE OF EQUATION MUST BE EQUAL.
MULTIPLY Fe ON RIGHT BY 2 MAKING 2 Fe'S ON EACH SIDE.
MULTIPLY CO BY 3 MAKING 3 O'S ON EACH SIDE.
THUS HAVE

$$Fe_2O_3 + C \rightarrow Fe + 3CO$$

MULTIPLY C ON LEFT BY 3 MAKING 3 C'S ON EACH SIDE.
THE BALANCED EQUATION

$$Fe_2O_3 + 3C \quad 2Fe + 3CO$$

CALCULATIONS

REACTING WEIGHTS - WEIGHTS OF COMPONENTS AND PRODUCTS OF REACTIONS

EXAMPLE: IRON ORE REDUCED WITH COKE.
WRITE BALANCED EQUATION AND THE MOLECULAR WEIGHTS UNDER FORMULAS OF THE EQUATION

$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$
$$160 \quad 3\times12 \quad 2\times56 \quad 3\times28$$

USING PROPORTIONS, SOLVE FOR THE DESIRED WEIGHTS OR PROPORTIONS.
AMOUNT OF COKE TO REDUCE A TON (2000 LBS.) OF ORE.

$$\frac{X}{2000} = \frac{36}{160} \quad X = 450 \text{ LBS OF COKE}$$

AMOUNT OF IRON FROM $\frac{1}{4}$ TON OF ORE.

$$\frac{X}{500} = \frac{112}{160} \quad X = 360 \text{ LBS OF IRON}$$

GAS COMPUTATIONS

GENERAL GAS LAW: $\frac{PV}{T} = \frac{P'V'}{T'}$

CAUTION - USE LIKE UNITS
P,V,AND T ARE GIVEN OR ORIGINAL CONDITIONS
P'V', AND T' ARE STANDARD OR NEW CONDITIONS
T AND T' ARE IN DEGREES ABSOLUTE

EXAMPLE: THE VOLUME OF 5 LITERS OF A GAS AT 20° C AND 740 MM OF MERCURY REDUCED TO STANDARD CONDITIONS,

$$V' = 4.53 \text{ LITERS}$$

WEIGHTS, VOLUMES, AND MOLECULAR WEIGHTS OF GASES - KNOWING ANY TWO, THE THIRD CAN BE FOUND.
MEASUREMENTS MUST BE IN GRAMS AND CUBIC CENTIMETERS.
CALCULATIONS HOLD ONLY FOR GASES AND VOLUME OF H_2O REFERS TO STEAM. (APPROX. 1600 TIMES THAT OF WATER)
MEASUREMENTS ALL CORRECTED TO STANDARD CONDITIONS.

$$\frac{\text{WEIGHT OF GAS}}{\text{MOLE. WT.}} = \frac{\text{VOLUME OF GAS}}{22{,}400}$$

RELATIVE VOLUMES - EXPRESSED BY MOLECULAR COEFFICIENTS OF EQUA.

$$\text{Ex. } 2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O$$
$$2\text{VOL.} \quad 5\text{VOL} \quad 4\text{VOL.} \quad 2\text{VOL.}$$

ORGANIC

CHEMISTRY OF A LARGE AND SPECIAL GROUP OF CARBON COMPOUNDS, OFTEN THE PRODUCTS OF LIVING ORGANISMS.

CARBON

NON-METAL; ATOMIC WEIGHT OF 12; VALENCE OF 4, OCCASSIONALLY 2; VERY INSOLUBLE. CHEMICALLY INACTIVE AT ORDINARY TEMPERATURES, BUT READILY UNITES WITH OXYGEN AT HIGH TEMPERATURES, THUS FORMS A PRIMARY FUEL AND ORE REDUCING AGENT. OCCURS AS DIAMOND, GRAPHITE OR PLUMBAGO, AND IN AMORPHOUS FORMS. COKE AND CHARCOAL ARE PRACTICALLY PURE CARBON.

HYDROCARBONS AND FUELS

PRODUCERS OF FLAME AND HEAT. FUELS ALL CONTAIN CARBON AND ALL EXCEPT COKE AND CHARCOAL CONTAIN HYDROGEN.

HYDROCARBONS ARE COMPOUNDS OF HYDROGEN AND CARBON. THEY ALL BURN THE NUMEROUS HYDROCARBONS FALL INTO DEFINITE SERIES.

METHANE, PARAFFIN, OR SATURATED SERIES - C_NH_{2N+2} PETROLEUM IS A MIXTURE OF MEMBERS OF THIS SERIES AND THEIR CHIEF SOURCE.

METHANE	CH_4	BUTANE	C_4H_{10}
ETHANE	C_2H_6	PENTANE	C_5H_{12}
PROPANE	C_3H_8	HEXANE	C_6H_{14}

EXCELLENT FUELS, HIGH HEAT AND NON-LUMINOUS FLAME. NATURAL GAS IS ALMOST PURE METHANE. BY FRACTIONAL DISTILLATION GASES, GASOLINE (MOSTLY HEXANE AND HEPTANE), BENZINE, KEROSENE, LUBRICATING OILS, AND PARAFFIN OR ASPHALT ARE SEPARATED FROM PETROLEUM.

ETHYLENE SERIES - C_NH_{2N} MADE BY HEATING ETHYL ALCOHOL.

ETHYLENE	C_2H_4	BUTYLENE	C_4H_8
PROPYLENE	C_3H_6	AMLYENE	C_5H_{10}

PRODUCERS OF VERY LUMINOUS FLAME

ACETYLENE SERIES - C_NH_{2N-2} ACETYLENE FORMED BY THE ACTION OF CALCIUM CARBIDE WITH WATER.

ACETYLENE	C_2H_2	BUTINE	C_4H_6
PROPINE	C_3H_4	PENTINE	C_5H_8

BURNS WITH A VERY HOT WHITE FLAME.

FUELS - SOLID: CARBON AS COKE OR COAL. LIQUID: HYDROCARBONS AND ALCOHOLS. GASEOUS: NATURAL GAS OR METHANE; COAL GAS, MOSTLY HYDROGEN AND METHANE, DISTILLATE OF COAL; PRODUCER GAS, CARBON MONOXIDE, USUALLY A BY-PRODUCT; WATER GAS, HYDROGEN AND CARBON MONOXIDE FORMED BY STEAM ON GLOWING COALS; AND OTHER HYDROCARBONS.

ALCOHOLS, ORGANIC ACIDS, AND ESTERS

ALCOHOLS - COMPOUNDS IN WHICH AN ATOM OF HYDROGEN IN A HYDROCARBON HAS BEEN REPLACED BY THE RADICAL OH. ARE ORGANIC BASES, BUT DO NOT IONIZE AS DO BASES.

ETHYL-C_2H_5OH, GRAIN, INDUSTRIAL, OR DENATURED ALCOHOL. PRODUCT OF THE FERMENTATION OF VEGETABLE MATTER. USED FOR FUEL, SOLVENT, ANTIFREEZE, PRODUCTION OF ETHYLENE, ETC

METHYL-CH_3OH, WOOD ALCOHOL. POISONOUS AND DANGEROUS DUE TO VOLATILITY. USED FOR SOLVENT AND FUEL.

A TINCTURE IS AN ALCOHOL SOLUTION.

FERMENTATION IS THE PROCESS BY WHICH YEAST PLANTS TRANSFORM SUGAR INTO ALCOHOL AND CARBON DIOXIDE

GLYCERIN, $C_3H_5(OH)_3$, AN ALCOHOL WITH MORE THAN ONE HYDROXYL RADICAL. BY-PRODUCT OF SOAP INDUSTRY AND USED FOR EXPLOSIVES, ETC.

ORGANIC ACIDS - PRODUCT OF THE OXIDATION OF AN ALCOHOL. ACID RADICAL, COOH. PRINCIPAL ACIDS: ACETIC, CH_3COOH. ACID IN VINEGAR. STEARIC AND PALMITIC OCCUR IN FATS AND OILS.

ALDEHYDES - PRODUCT OF ALCOHOLS AND AN INTERMEDIARY BETWEEN ALCOHOLS AND ORGANIC ACIDS. FORMALDEHYDE, OR THE 40% SOLUTION, FORMALIN, IS A COMMON EXAMPLE.

ESTERS - PRODUCT OF AN ALCOHOL AND ORGANIC ACID OTHER THAN WATER. ORGANIC SALTS, BUT DO NOT IONIZE AS DO SALTS. ACETATES, WAXES, FATS, AND OILS ARE ESTERS. THEY ARE ALMOST INSOLUBLE IN WATER.

HARD WATER - TEMPORARY HARDNESS IS DUE TO FE OR CA BICARBONATE AND CAN BE SOFTENED BY BOILING. PERMANENT HARDNESS DUE TO CA OR MG SULPHATE AND SOFTENED BY NA CMPDS

ORGANIC

CARBOHYDRATES

ORGANIC COMPOUNDS CONTAINING CARBON WITH HYDROGEN AND OXYGEN IN THE SAME RATIO AS IN WATER.

STARCH - $(C_6H_{10}O_5)_X$, POTATOES, CORN, RICE, AND WHEAT ARE SOURCES OF STARCH. PRIMARILY A FOOD, ALSO OTHER USES AS CLOTH STIFFENER, ETC. INSOLUBLE IN COLD WATER BUT DISSOLVES IN HOT. TURNS BRIGHT BLUE IN CONTACT WITH IODINE, A TEST.

STARCH WHEN HEATED TURNS TO DEXTRIN. EXAMPLES, BREAD CRUST, THE BROWNISH GUM ON STAMPS.

SUGARS - SAP OF CANE, BEETS, TREES, AND GRAPES. COMMON CANE SUGAR IS SUCROSE, $C_{12}H_{22}O_{11}$. LEVULOSE IS SUGAR FROM FRUITS AND HONEY. SIMPLER SUGARS, FRUCTOSE AND GLUCOSE, OBTAINED BY BOILING CANE SUGAR. A MAJOR FOOD.

CELLULOSE - $(C_6H_{10}O_5)_N$, CELL WALLS OF PLANTS; WOOD, COTTON, AND LINEN. RAYON, EXPLOSIVES, SOME PLASTICS, PAPER, AND CLOTH ARE CELLULOSE PRODUCTS. CHEMICALLY INACTIVE. SOLUBLE IN MIXTURE OF COPPER AND AMMONIUM HYDROXIDES.

PLANTS AND SOIL

PLANTS COMPOSED OF ORGANIC MATTER (THAT WHICH CAN BE BURNED), MINERAL OR ASH, AND WATER.

ORGANIC MATTER CONSISTS OF CARBOHYDRATES; ESTERS; AND NITROGEN COMPOUNDS, MOSTLY PROTEINS.

PLANTS GROW BY ABSORBING COMPOUNDS DISSOLVED IN THE WATER OF THE SOIL, AND BY PHOTOSYNTHESIS.

CARBOHYDRATES ARE CHANGED TO PROTEINS, ETC. BY COMBINING WITH NITROGEN AND OTHER ELEMENTS.

PLANTS ABSORB CARBON DIOXIDE TO FORM CARBOHYDRATES AND GIVE BACK OXYGEN TO THE AIR.

NITROGEN FIXATION - NITROGEN REPLACED IN SOIL BY FERTILIZERS OR BY LEGUMINOUS PLANTS, SUCH AS PEAS AND BEANS, WHICH SUPPORT BACTERIA THAT FIXES NITROGEN IN THE SOIL.

OSMOSIS - PROCESS BY WHICH LIQUIDS DIFFUSE THRU A SEMI-PERMEABLE MEMBRANE. METHOD USED BY PLANTS TO ABSORB MOISTURE FROM SOIL.

ORGANIC

PHOTOSYNTHESIS - PROCESS, DEPENDENT UPON SUNLIGHT, BY WHICH PLANTS PRODUCE CARBOHYDRATES FROM WATER AND CARBON DIOXIDE.

FOODS

CONSIST OF ORGANIC MATTER, AND INORGANIC OR MINERAL MATTER IN SMALL QUANTITIES, AND ALSO WATER.

CARBOHYDRATES-SUPPLY ENERGY, FORM FAT IF EATEN IN EXCESS.

FATS AND OILS-SUPPLY HEAT AND ENERGY. OCCUR IN ANIMAL TISSUES, MILK, OLIVE, COCONUT, PEANUT, CORN AND COTTON SEED OIL.

PROTEINS-COMPLEX ORGANIC COMPOUNDS CONTAINING NITROGEN AND OTHER ELEMENTS. BUILD UP BODY TISSUES, REPAIRS THEM. OCCUR IN LEAN MEAT, EGG WHITES, GLUTEN OF WHEAT FLOUR, MILK, ETC.

VITAMINS-SUBSTANCES IN FOODS NECESSARY FOR HEALTH,

VITAMIN A -FAT SOLUBLE. AIDS GROWTH, PREVENTS RICKETS. PREVALENT IN MILK, EGGS, LEAFY VEGETABLES, AND BUTTER.

VITAMIN B -WATER SOLUBLE. HELPS PREVENT SKIN TROUBLE, BERIBERI, PELLAGRA, AND NEURITIS. FOUND IN HULLS OF GRAINS AND IN FRESH FRUITS AND VEGETABLES.

VITAMIN C -WATER SOLUBLE. PREVENTS SCURVY AND HELPS RESIST INFECTIOUS DESEASES. PLENTIFUL IN FRESH FRUITS AND VEGETABLES. EASILY DESTROYED BY HEATING, EVEN BY PASTEURIZATION.

VITAMIN D -FAT SOLUBLE. HELPS CALCIFICATION OF BONES AND TEETH. SUNLIGHT, ULTRA VIOLET RAYS, AND COD-LIVER OIL SUPPLY THIS VITAMIN.

VITAMIN E -FAT SOLUBLE. NECESSARY FOR REPRODUCTION. OCCURS IN GREEN VEGETABLES, MILK FAT, ETC.

ENZYMES - CATALYSTS IN PLANTS AND ANIMALS THAT AID IN BREAKING UP ORGANIC COMPOUNDS.

HEAT OR FUEL ENERGY IN FOODS MEASURED IN LARGE CALORIES (HEAT REQ'D TO RAISE A KG. OF WATER 1°C.)

THE NINETY-TWO ELEMENTS

THEIR SYMBOLS, ATOMIC NUMBERS AND ATOMIC WEIGHTS

Name	Symbol	Atomic Number	Atomic Weight
Actinium	Ac	89	
Alabamine	Am	85	211
Aluminum	Al	13	26.97
Antimony	Sb	51	121.76
Argon	A	18	39.944
Arsenic	As	33	74.93
Barium	Ba	56	137.36
Beryllium	Be	4	9.02
Bismuth	Bi	83	209.00
Boron	B	5	10.82
Bromine	Br	35	79.916
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Carbon	C	6	12.00
Cerium	Ce	58	140.13
Caesium	Cs	55	132.81
Chlorine	Cl	17	35.457
Chromium	Cr	24	52.01
Cobalt	Co	27	58.94
Columbium	Cb	41	93.3
Copper	Cu	29	63.57
Dysprosium	Dy	66	162.46
Erbium	Er	68	167.64
Europium	Eu	63	152.0
Fluorine	F	9	19.00
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.72
Germanium	Ge	32	72.60
Gold	Au	79	197.2
Hafnium	Hf	72	178.6
Helium	He	2	4.002
Holmium	Ho	67	163.5
Hydrogen	H	1	1.0078
Indium	In	49	114.8
Illinium	Il	61	147
Iodine	I	53	126.92
Iridium	Ir	77	193.1
Iron	Fe	26	55.84
Krypton	Kr	36	83.7
Lanthanum	La	57	138.92
Lead	Pb	82	207.22
Lithium	Li	3	6.940
Lutecium	Lu	71	175.0
Magnesium	Mg	12	24.32
Manganese	Mn	25	54.93
Mazurium	Mz	43	100
Mercury	Hg	80	200.61
Molybdenum	Mo	42	96.0
Neodymium	Nd	60	144.27
Neon	Ne	10	20.183
Nickel	Ni	28	58.69
Nitrogen	N	7	14.008
Osmium	Os	76	190.8
Oxygen	O	8	16.0000
Palladium	Pd	46	106.7
Phosphorus	P	15	31.02
Platinum	Pt	78	195.23
Polonium	Po	84	210
Potassium	K	19	39.10
Praseodymium	Pr	59	140.92
Prot-Actinium	Pa	91	231
Radium	Ra	88	225.97
Radon	Rn	86	222
Rhenium	Re	75	186.31
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.44
Ruthenium	Ru	44	101.7
Samarium	Sm	62	150.43
Scandium	Sc	21	45.10
Selenium	Se	34	79.2
Silicon	Si	14	28.06
Silver	Ag	47	107.880
Sodium	Na	11	22.997
Strontium	Sr	38	87.63
Sulphur	S	16	32.06
Tantalum	Ta	73	181.4
Tellurium	Te	52	127.5
Terbium	Tb	65	159.2
Thallium	Tl	81	204.39
Thorium	Th	90	232.12
Thulium	Tm	69	169.4
Tin	Sn	50	118.70
Titanium	Ti	22	47.90
Tungsten	W	74	184.0
Uranium	U	92	238.14
Vanadium	V	23	50.95
Virginium	Va	87	224
Xenon	Xe	54	130.2
Ytterbium	Yb	70	173.5
Yttrium	Y	39	88.92
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.22

Element	Melting Point	Boiling Point	Specific Gravity	Specific Heat	Molecular Formula	Valence
Aluminum	658°		2.71	0.22		3
Antimony	630°	White heat	6.7	0.052		3; 5
Argon	−189°	−186°			Ar	0
Arsenic		615° (sublimes)	5.7	0.083	As_4	3; 5
Bismuth	271°	1,450°	9.8	0.031		3
Bromine	−7°	59°	3.4	0.084	Br_2	1
Calcium	810°	1,170°	1.6	0.18		2
Carbon:						
Graphite	3,500°	4,200°	2.2	0.454		
Diamond		4,200° (sublimes)	3.5	0.45		
Chlorine	−102°	−34°	1.33 (liquid)		Cl_2	
Chromium	1,615°	2,200°	7.1	0.100		3; 6
Copper	1,083°	2,100°	8.9	0.094		1; 2
Fluorine	−223°	−187°	1 (liquid)		F_2	1
Gold	1,063°	2,300°	19.3	0.0316		3
Hydrogen	−259.1°	−253°			H_2	1
Iodine	113°	184°	4.95	0.054	I_2	1
Iron (wrought)	1,535°	3,000°	7.8	0.112		2; 3
Lead	327°	1,620°	11.4	0.031		2
Lithium	186°	1,200°	0.53	0.88		1
Magnesium	650°	1,110°	1.75	0.245		2
Manganese	1,260°	1,900°	7.2	0.11		2
Mercury	−38.9°	357°	13.56	0.032	Hg	1; 2
Nickel	1,452°	2,900°	8.9	0.109		2
Nitrogen	−210°	−196°			N_2	3; 5
Oxygen	−218°	−183°			O_2	2
Phosphorus (White)	44°	280°	1.83	0.202		
Phosphorus (Red)			2.2	0.17	P_4	3; 5
Platinum	1,755°	4,300°	21.5	0.04		4
Potassium	62°	760°	0.86	0.165	K	1
Radium	960°	1,140°	5	0.03		2
Silicon	1,420°	2,600°	2.4	0.181		4
Silver	960°	1,950°	10.47	0.057		1
Sodium	97.5°	880°	0.97	0.29	Na	1
Sulphur (Rhombic)	113°	444°	2.07			
Sulphur (Prismatic)	119°	444°	1.95	0.18		2; 4; 6
Tin	232°	2,260°	7.3	0.0562		2; 4
Tungsten	3,370°	5,900°	19.5			6
Zinc	419°	907°	7.1	0.096		2

LENGTH. 1 meter (1 m.) = 10 decimeters = 100 centimeters (100 cm.) = 1000 millimeters (1000 mm.).

1 kilometer = 1000 meters (1000 m.) = 0.6214 mile
1 decimeter = 0.1 = 10 centimeters = 3.937 inches
1 meter = 1.094 yards = 3.286 ft. = 39.37 in.

VOLUME. 1 liter = 1000 cubic centimeters (1000 c.c.) = a cube 10 cm. × 10 cm. × 10 cm.

1 liter = 0.03532 cu. ft. = 61.03 cu. in. = 1.057 quarts (U.S.) or 1.136 quarts (Brit.) = 34.1 fl. oz. (U.S.) = 35.3 oz. (Brit.)
1 fluid ounce (U.S.) = 29.57 c.c. 1 ounce (Brit.) = 28.4 c.c.
1 cu. ft. = 28.32 liters.

WEIGHT. 1 gram (g.) = wt. of 1 c.c. of water at 4° C. 1 kilogram = 1000 g. 1 gram = 10 decigrams = 100 centigrams (100 cgm.) = 1000 milligrams (1000 mgm.).

1 kilogram = 2.205 lbs. avoird. (U.S. and Brit.).
1000 kilograms = 2205 lbs. = 1 metric ton.
1 lb. avoird. = 453.6 g.
1 oz. avoird. (U.S. and Brit.) = 28.35 g. 100 g. = 3.5 oz.

VAPOR PRESSURES OF WATER

Both the Fahrenheit (F), Centigrade (C) temperatures are given.

Temperature. F.		Pressure, mm.	Temperature. F.		Pressure. mm.
32°	0°	4.6	71.6°	22°	19.7
41	5	6.5	73.4	23	20.9
46.4	8	8.0	75.2	24	22.2
48.2	9	8.6	77.0	25	23.5
50.0	10	9.2	78.8	26	25.0
51.8	11	9.8	80.6	27	26.5
53.6	12	10.5	82.4	28	28.1
55.4	13	11.2	84.2	29	29.8
57.2	14	11.9	86.0	30	31.5
59.0	15	12.7	87.8	31	33.4
60.8	16	13.5	89.6	32	35.4
62.6	17	14.4	91.4	33	37.4
64.4	18	15.4	93.2	34	39.6
66.2	19	16.3	95.0	35	41.8
68.0	20	17.4			
69.8	21	18.5	212.0	100	760.0

Name	Formula	Molecular Weight	Vapor Density (*Hydrogen Standard*)	Specific Gravity (*Air Standard*)	Weight of 1 Liter in Grams (*Standard Conditions*)
Acetylene	C_2H_2	26.0	13	0.906	17
Air	.....		14.44	1.000	29
Ammonia	NH_3	17.0	8.5	0.596	0.77
Argon	A	39.9	19.9	1.378	78
Carbon dioxide	CO_2	44.0	22	1.529	98
Carbon monoxide	CO	28.0	14	0.967	25
Chlorine	Cl_2	71.0	35.5	2.491	20
Ethane	C_2H_6	30.0	15.0	1.049	1.35
Helium	He	4.0	2.0	0.137	0.178
Hydrogen	H_2	2.016	1.0	0.069	0.089
Hydrogen chloride	HCl	36.5	18.25	1.268	1.64
Hydrogen sulphide	H_2S	34.0	17.0	1.186	1.53
Methane	CH_4	16.0	8.0	0.554	0.717
Nitric oxide	NO	30.0	15.0	1.035	1.34
Nitrogen	N_2	28.0	14.0	0.967	1.25
Nitrous oxide	N_2O	44.0	22.0	1.530	1.98
Oxygen	O_2	32.0	16.0	1.105	1.429
Sulphur dioxide	SO_2	64.0	32.0	2.264	2.88

AVERAGE COMPOSITION OF DIFFERENT FUEL GASES

Constituent	Ohio Natural Gas	Coal Gas	Water Gas	Producer Gas
H_2	0.9	41.3	52.88	10.90
CH_4	89.5	43.6	2.16	
C_6H_6	9.3			
CO	0.4	6.4	36.80	20.10
CO_2	0.3	2.0	3.47	8.50
N_2	0.2	1.2	4.69	59.90
O_2	0.0	0.3		
Other hydrocarbons	0.3	5.4		0.60
Heat values in calories per cubic meter	8120	5333	2738	1402

ELECTROMOTIVE SERIES

Cæsium	Aluminum	Nickel	Antimony
Rubidium	Manganese	Tin	Mercury
Potassium	Zinc	Lead	Silver
Sodium	Chromium	**Hydrogen**	Palladium
Lithium	Cadmium	Copper	Platinum
Calcium	Iron	Arsenic	Gold
Magnesium	Cobalt	Bismuth	Osmium

COMPARATIVE ABUNDANCE OF THE ELEMENTS IN NATURE

Elements (in Order of Abundance)	Percentage Composition of the Solid Crust of the Earth	Percentage Composition of Sea Water
Oxygen	49.00	85.79
Silicon	25.00	
Aluminum	8.00	
Iron	5.1	
Calcium	3.6	0.05
Potassium	2.8	0.04
Sodium	2.6	1.14
Magnesium	2.00	0.14
Hydrogen	0.23	10.67
Titanium	0.41	
Carbon	0.20	0.002
Chlorine	0.06	2.07
All others	1.00	0.098
Total	100.00	100.000

COMPOSITION OF THE ATMOSPHERE

	Percentage by Volume	Percentage by Weight
Nitrogen	78.08	75.51
Oxygen	20.95	23.14
Carbon dioxide	0.03	0.05
Argon	0.93	1.29
Neon		
Helium		
Krypton	0.01	0.01
Xenon		
Hydrogen	100.00	100.00

COMPOSITION OF THE HUMAN BODY

	Per Cent		Per Cent
Oxygen	65.0	Sodium	0.15
Carbon	18.0	Chlorine	0.15
Hydrogen	10.0	Magnesium	0.05
Nitrogen	3.0	Iron	0.004
Calcium	2.0	Iodine	*trace*
Phosphorus	1.0	Fluorine	*trace*
Potassium	0.35	Silicon	*trace*
Sulphur	0.25		

53 AVERAGE COMPOSITION OF EDIBLE PORTION OF TYPICAL FOODS EXPRESSED IN GRAMS PER 100 GRAMS OF FOOD

Food	Water	Protein	Fat	Carbohydrate	Ash	Fuel Value (Cal. per 100 g.)
Almonds	4.8	21.0	54.9	17.3	2.0	647
Apples	84.6	0.4	0.5	14.2	0.3	63
Asparagus	94.0	1.8	0.2	3.3	0.7	22
Bacon (smoked)	20.2	9.9	64.8	—	5.1	623
Bananas	75.3	1.3	0.6	22.0	0.8	99
Beans (dried)	12.6	22.5	1.8	59.6	3.5	345
Beans (string)	89.2	2.3	0.3	7.4	0.8	42
Beef (lean steak)	70.0	21.0	7.9	—	1.1	155
Beef (slightly fat)	73.8	22.1	2.9	—	1.2	115
Beets	87.5	1.6	0.1	9.7	1.1	46
Bread (corn)	38.9	7.9	4.7	46.3	2.2	259
Bread (graham)	35.7	8.9	1.8	52.1	1.5	260
Bread (white)	35.3	9.2	1.3	53.1	1.1	260
Butter	11.0	1.0	85.0	—	3.0	769
Cabbage	91.5	1.6	0.3	5.6	1.0	32
Carrots	88.2	1.1	0.4	9.3	1.0	45
Celery	94.5	1.1	0.1	3.3	1.0	19
Chestnuts	45.0	6.2	5.4	42.1	1.3	242
Chicken	63.7	19.3	16.3	—	1.0	224
Codfish (fresh)	82.6	15.8	0.4	—	1.2	67
Corn (green)	75.4	3.1	1.1	19.7	0.7	101
Dates	13.8	1.9	2.5	70.6	1.2	313
Eggs	73.7	14.8	10.5	—	1.0	154
Figs	18.8	4.3	0.3	74.2	2.4	317
Ham (lean, smoked)	53.5	20.2	20.8	—	5.5	268
Lettuce	94.7	1.2	0.3	2.0	0.9	16
Macaroni	78.4	3.0	1.5	15.8	1.3	89
Milk	87.0	3.3	4.0	5.0	0.7	69
Oatmeal	7.3	16.1	7.2	67.5	1.9	400
Olive oil	—	—	100.0	—	—	900
Oranges	86.9	0.8	0.2	11.6	0.5	51
Peaches	89.4	0.7	0.1	9.4	0.4	41
Peanuts	9.2	25.8	38.6	24.4	2.0	548
Peas (green)	74.6	7.0	0.5	16.9	1.0	100
Plums	78.4	1.0	—	20.1	0.5	84
Potatoes	78.3	2.2	0.1	18.4	1.0	83
Prunes (dried)	22.3	2.1	—	73.3	2.3	302
Raisins	14.6	2.6	3.3	76.1	3.4	345
Rice	12.3	8.0	0.3	79.0	0.4	351
Salmon	64.6	21.2	12.8	—	1.4	200
Spinach	92.3	2.1	0.3	3.2	2.1	24
Strawberries	90.4	1.0	0.6	7.4	0.6	39
Tomatoes	94.3	0.9	0.4	3.9	0.5	23
Turnips	89.6	1.3	0.2	8.1	0.8	40
Wheat flour	11.9	13.3	1.5	72.7	0.6	357

These values are taken from *Bulletin No. 28*, office of Experiment Station, Washington, D.C. The fuel values are obtained from the following formula:

Cal. in 100 g. $= 4\,P + 9\,F + 4\,C$, in which P, F, and C represent respectively the number of grams of protein, fat, and carbohydrates in 100 g. of the food.

BORAX BEAD TESTS

A borax bead is made by fusing borax in a small loop of platinum wire. The bead is then dipped into some of the unknown solid and refused. After cooling, the following colors are obtained.

Element	Oxidizing Flame	Reducing Flame
Ni	Violet (hot), Brown (cold)	Grey
Mn	Violet	Colorless
Fe	Yellow	Green
Cu	Blue	Red (if concentrated)
Cr	Green	Green
Co	Blue	Blue

FLAME TESTS

The substance to be tested is moistened with concentrated hydrochloric acid and placed, by means of a clean platinum wire, into the Bunsen flame.

Color Imparted to Flame	Substance Indicated
Fluffy Yellow	Sodium
Violet	Potassium
Deep Red	Strontium or Lithium
Brick Red	Calcium
Greenish-Yellow or Green	Copper, Barium or Boric Acid
Pale Blue	Arsenic
Bright Blue	Copper Chloride

SOLUBILITIES OF BASES AND SALTS IN WATER AT 18°

	K	Na	Li	Ag	Ca	Sr	Ba	Mg	Zn	Pb
Cl	32.95 3.9	35.86 5.42	77.79 13.3	$0.0_3 16$ $0.0_4 10$	73.19 5.4	51.09 3.0	37.24 1.7	55.81 5.1	203.9 9.2	0.955 0.034
Br	65.86 4.6	88.76 6.9	168.7 12.6	$0.0_4 1$ $0.0_6 6$	143.3 5.2	96.52 3.4	103.6 2.9	103.1 4.6	478.2 9.8	0.803 0.022
I	137.5 6.0	177.9 8.1	161.5 8.5	$0.0_6 35$ $0.0_7 1$	200.0 4.8	169.2 3.9	201.4 3.8	148.2 4.1	419.0 6.9	0.063 0.001
F	92.56 12.4	4.44 1.06	0.27 0.11	195.4 13.5	0.0016 $0.0_3 2$	0.012 0.001	0.16 $0.0_2 92$	0.0076 $0.0_2 14$	0.005 $0.0_3 5$	0.06 0.003
NO_3	30.34 2.6	83.97 7.4	71.43 7.3	213.4 8.4	121.8 5.2	66.27 2.7	8.74 0.33	74.31 4.0	117.8 4.7	51.66 1.4
ClO_3	6.6 0.52	97.16 6.4	313.4 15.3	12.25 0.6	179.3 5.3	174.9 4.6	25.0 0.8	126.4 4.7	183.9 5.3	150.6 3.16
BrO_3	6.38 0.38	36.67 2.2	152.5 8.20	0.59 0.025	85.17 2.3	30.0 0.9	0.8 0.02	42.86 1.5	58.43 1.8	1.3 0.03
IO_3	7.62 0.35	8.33 0.4	80.43 3.84	0.004 $0.0_3 14$	0.25 0.007	0.25 $0.0_2 57$	0.05 0.001	6.87 0.26	0.83 0.02	0.0019 $0.0_4 3$
OH	110.0 14.0	107.0 20.0	12.04 5.0	0.01 0.001	0.17 0.02	0.77 0.063	3.7 0.22	0.001 $0.0_3 2$	$0.0_3 5$ $0.0_4 5$	0.01 $0.0_3 4$
SO_4	11.11 0.62	16.83 1.15	35.64 2.8	0.55 0.020	0.20 0.015	0.011 $0.0_3 6$	$0.0_3 23$ $0.0_4 10$	35.43 2.8	53.12 3.1	0.0041 $0.0_3 13$
CrO_4	63.1 2.7	61.21 3.30	111.6 6.5	0.0026 $0.0_4 19$	0.4 0.03	0.12 0.006	$0.0_3 38$ $0.0_4 15$	73.0 4.3	— —	$0.0_4 2$ $0.0_6 5$
C_2O_4	30.27 1.6	3.34 0.24	7.22 0.69	0.0035 $0.0_3 12$	$0.0_3 56$ $0.0_4 43$	0.0046 $0.0_3 27$	0.0086 $0.0_3 38$	0.03 0.0027	$0.0_3 64$ $0.0_4 47$	$0.0_3 15$ $0.0_5 5$
CO_3	108.0 5.9	19.39 1.8	1.3 0.17	0.003 $0.0_3 1$	0.0013 $0.0_3 13$	0.0011 $0.0_4 7$	0.0023 $0.0_3 11$	0.1 0.01	0.001 $0.0_4 8$	$0.0_3 1$ $0.0_5 4$

In each square is given (as **upper number**) the solubility in grams of anhydrous salt or base in 100 cc. of water, and (as **lower number**) the number of gram-molecular weights contained in 1 liter of the saturated solution, *i.e.* the molal solubility.

THE PERIODIC TABLE

Periods	Group 0	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
Formula of oxides...		R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4
Formula of hydrides.....		RH	RH_2	RH_3	RH_4	RH_3	RH_2	RH	...
		A 1	B H 1.008	A	B	A	B	A	B	A	B	A	B	
First short period.....	He 2 4.00	Li 3 6.94		4 Be 9.02		5 B 10.82		6 C 12.000		7 N 14.008		8 O 16.00		9 F 19.00		
Second short period.....	Ne 10 20.2	Na 11 22.997		12 Mg 24.32		13 Al 26.97		14 Si 28.06		15 P 31.027		16 S 32.064		17 Cl 35.457		
First long period — Even series..	A 18 39.91	K 19 39.096		Ca 20 40.07		Sc 21 45.10		Ti 22 48.1		V 23 50.96		Cr 24 52.01		Mn 25 54.93		26 Fe 27 Co 28 Ni
First long period — Odd series ..		29 Cu 63.57		30 Zn 65.38		31 Ga 69.72		32 Ge 72.60		33 As 74.96		34 Se 79.2		35 Br 79.916		55.84 58.94 58.68
Second long period — Even series..	Kr 36 82.9	Rb 37 85.44		Sr 38 87.63		Y 39 88.9		Zr 40 91.		Cb 41 93.1		Mo 42 96.0		... 43		44 Ru 45 Rh 46 Pd
Second long period — Odd series ..		47 Ag 107.88		48 Cd 112.41		49 In 114.8		50 Sn 118.7		51 Sb 121.77		52 Te 127.5		53 I 126.932		101.7 102.91 106.7
Third long period — Even series..	Xe 54 130.2	Cs 55 132.81		Ba 56 137.37		The Rare Earth Metals *		Ce 58 140.25								
Third long period — Odd series ..		...		...				...								
Fourth long period — Even series..	..	...		...		...		Hf 72 178.6		Ta 73 181.5		W 74 184.0		... 75		76 Os 77 Ir 78 Pt
Fourth long period — Odd series ..	....	79 Au 197.2		80 Hg 200.61		81 Tl 204.39		82 Pb 207.20		83 Bi 209.00		84 Po 210.0		85		190.8 193.1 195.23
Fifth long period.....	Rn 86 222.	... 87		Ra 88 225.95		Ac 89 230		Th 90 232.15		Ux 91 234.2		U 92 238.17				

* 57 Lanthanum 58 Cerium 59 Praseodymium 60 Neodymium 61 Illinium 62 Samarium 63 Europium 64 Gadolinium
65 Terbium 66 Dysprosium 67 Holmium 68 Erbium 69 Thulium 70 Ytterbium 71 Lutecium

ENGINEERING MECHANICS

Stress
Beams
Reinforced Concrete
Stresses In Beams

STRESS

$d = \frac{PL}{AE}$ — d = deformation, in.; P = load or force, lb.; A = x-section area, in.^{2}; E = modulus of elast., lb/in.^{2}; steel - 30×10^6.

$s = \frac{P}{A}$ — L = length, in.

$E_s = \frac{s}{\Delta}$ — E_s = mod. of elast. in shear, lb/in.^{2}; Δ = lateral deform.; s = stress, lb/in.^{2}

Poisson's ratio

$\frac{\Delta}{d} = \frac{1}{3}$ to $\frac{1}{4}$

Stress due to temp. change

$s = \alpha t E$ — α = coeff. of expan. = .0000065 "/° F for steel; t = temp. change; s = stress, lb/in.^{2}

Thin cylinders

$s_l = \frac{pr}{2t}$ — s_l = longitudinal stress; p = pressure, lb/in.^{2}; r = internal rad., in.; t = shell thickness, in.

$s_t = \frac{pr}{t}$ — s_t = tangential stress

Riveted joints

Single shear; P = load, lb.

$P = s_s n A$ — s_s = shearing stress; n = total no. rivets; A = area of rivet, in.^{2}

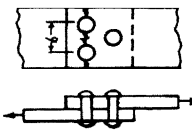
Double shear

$P = 2 s_s n A$; For steel, s_s is 16000 lb/in.^{2}

STRESS

Tension

$P = s_t t (b - n_1 d_1)$



s_t = tensile stress; t = plate thick., in.; b = plate width or pitch, in.; n_1 = no. of rivets in row; d_1 = rivet hole dia., in.

Bearing

$P = s_b n A$ — s_b = bearing stress = 20000 lb/in.^{2} steel

Efficiency of joint

$Eff = \frac{s_t + b}{P}$

Safety factor

$S = \frac{S_{ult.}}{S.F.}$ — S allowable or working stress; $S_{ult.}$ = ultimate stress; $S.F.$ = safety factor

Torsion

$\phi = \frac{M_t L}{G I_p}$ — ϕ = angle of twist, rad. 1 radian = 57.3°; M_t = twisting mom., in.*; G = modulus of shear. G for steel = 12×10^6 lb/in.^{2}; F = twisting force, lb.; L = length, in.; I_p = J = polar moment of inertia., in.*; d = diameter of shaft, in.

for shaft

$\phi = \frac{16 F L}{G \pi d^3}$

BEAMS

V_x = shear at x $W = wl$ = load
M = bending mom. (maximum) w = wgt./ft.
l = length, ft.
Δ = deflection, max. L = length, in.
M_x = bend. mom. at x. I = moment of inertia, in⁴
R = reaction

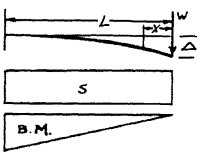
Cantilever, load at end

$R = V_x = -W$

$M = WL$

$\Delta = \frac{WL^3}{3EI}$

$M_x = Wx$



Cantilever, uniform load

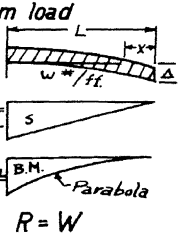
$V_x = \frac{Wx}{L} = wx$

$M = \frac{WL}{2} = \frac{wL^2}{2}$

$\Delta = \frac{WL^3}{8EI} = \frac{wL^4}{8EI}$

$M_x = \frac{Wx^2}{2L} = \frac{wx^2}{2}$

$R = W$



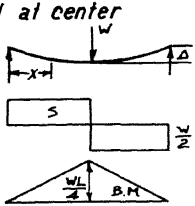
Simple beam, load at center

$V = \frac{W}{2} = R$

$M = \frac{WL}{4}$

$\Delta = \frac{WL^3}{48EI}$

$M_x = \frac{Wx}{2}$



BEAMS

Simple beam, load at any point

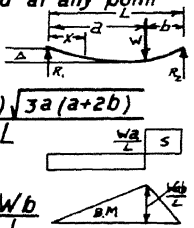
$V = R$

$M = \frac{Wab}{L}$

$\Delta = \frac{Wab\,(a+2b)\sqrt{3a(a+2b)}}{27EIL}$

$M_x = \frac{Wbx}{L}$

$R_2 = \frac{Wa}{L}$, $R_1 = \frac{Wb}{L}$



Simple beam, uniform load

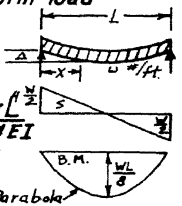
$V_x = \frac{W(L-2x)}{2L}$

$M = \frac{WL}{8} = \frac{wL^2}{8}$

$\Delta = \frac{5WL^3}{384EI} = \frac{5wL^4}{384EI}$

$M_x = Wx(l-x)/2l$

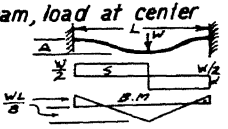
$R = W/2$



Fixed-end beam, load at center

$M = \frac{WL}{8}$

$\Delta = \frac{WL^3}{192EI}$



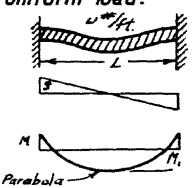
Fixed end beam, uniform load.

$V_x = \frac{W(L-2x)}{2L}$

$M = \frac{WL}{12} = \frac{wL^2}{12}$

$M_1 = \frac{WL}{24} = \frac{wL^2}{24}$

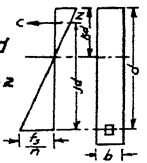
$\Delta = \frac{WL^3}{384EI}$



REINFORCED CONCRETE

$K = \sqrt{2pn + (pn)^2} - pn$

$J = L - \frac{K}{3}$ $\quad Z = \frac{1}{3} Kd$



$M = f_s A_s jd = f_s pjbd^2$

$M = \frac{1}{2} f_c kjbd^2$

$bd^2 = \frac{M}{f_s pj} = \frac{M}{\frac{1}{2} f_c kj}$

p = steel ratio $= \frac{1}{\frac{2 f_s}{f_c}\left[\frac{f_s}{n f_c} + 1\right]}$

M = bending moment

A_s = effective cross-section of metal.

A_c = net x-section concrete

b = width of section

f_c = compressive stress in concrete, lb/in.²

f_s = tensile stress in metal, lb/in.²

$n = \frac{E_s}{E_c} = \frac{\text{modulus steel}}{\text{modulus concrete}}$

n commonly = 15

L = length of span; in.

Shearing stress

$v = \frac{s}{7} \frac{V}{bd}$

v = unit shearing stress, lb/in.²

V = shear, lb.

b = width

d = depth

Bond strength

$u = \frac{s}{7} \frac{V}{\Sigma_o d}$

Σ_o = sum of perimeters of bars in set, in.

u = bond stress per in.² of surface of bar.

Concrete weighs 150 lb/ft³

Modulus of elasticity of concrete varies from $\frac{1}{15} E_s$ to $\frac{1}{10} E_s$.

STRESSES IN BEAMS

Flexure or bending stress

$s = \frac{Mc}{I} = \frac{My}{I}$

$s = \frac{M}{I/c} = \frac{M}{I/y}$

s = stress, max. at outer fibre, lb/in.²

M = bending mom., in inch pounds

$c = y$ = distance stressed fibre (usually outer) is from neutral axis (thru C.G. of beam), inches

I/c = section modulus

I = moment of inertia of the section about neut. axis, in.⁴

Shearing stress

$s = \frac{VQ}{Ib} = \frac{VAy}{Ib} = v$

$Q = Ay$

$s = v$ = shearing str., 12000 lb/in.² common value.

A = area of section cut thru from outside to point where shear desired, neut. axis usually, in.²

y = dist from neut. axis to centroid of area A.

I = mom. of inertia of section ab't neut. axis, in.

b = beam width at pt. of shear, in.

Only the figures are given, decimal point must be figured out independently.

Multiplication:- 2×3 — Set index (figure 1) of C scale at 2 on D scale, read under 3 on C scale the answer, 6, on D scale.

Division:- $3 \div 4$ — Set 4 on C scale opposite 3 on D scale and under the index of C scale read on the D scale the answer, .75.

Square Root:- $\sqrt{2}$ — Set indicator on 2 on first half of A scale, read on D scale the answer 1.414. Numbers of even digets (10 to 99, 1000 to 9999), set indicator on second half of A scale.

Logarithms$_{10}$:- Log_{10} — Set 2 on C scale opposite index of D scale, read on L scale at index line the answer, .301.

Powers:- $\circ^3$ — To 2 on LL2 scale set right index of C scale, opposite 3 on C scale read on LL3 the answer, 8.

$.002^3 = x$ — $.002^3 = 1/(500)^3$

$(500)^3 = 125{,}000{,}000$ (See Above)

$x = 1/125{,}000{,}000 = .000{,}000{,}008$

$\circ^{.03}$ — To 2 on LL2 set right index of C scale, opposite 3 on C scale read on LL1 scale the answer, 1.021.

$.002^{.03} = 1/(500)^{.03} = x$

$(500)^{.03}$: To 500 on LL2 scale set right index of C scale, opposite 3 on C scale read on LL2 scale the answer, 1.205.

$x = 1/1.205 = .830$

PROPERTIES OF METALS

Metal or Composition	Chemical Symbol	Specific Gravity	Weight per Cubic Inch, Pound	Weight per Cubic Foot, Pounds	Melting Point, Deg. F.	Structure*	Linear Expansion per Unit Length per Deg. F.	Electric Conductivity; Silver = 100
Aluminum	Al	2.56	0.0924	159.7	1218	*M*	0.00001233	63.00
Antimony	Sb	6.71	0.2422	418.7	1166	*B*	0.00000587	3.59
Barium	Ba	3.75	0.1354	234.0	1562	*M*	.....	30.61
Bismuth	Bi	9.80	0.3538	611.5	520	*B*	0.00000731	1.40
Boron	B	2.60	0.0939	162.2	4000-4500	*H*	.....	.....
Brass: 80 C., 20 Z.	...	8.60	0.3105	536.6				
70 C., 30 Z.	...	8.40	0.3032	524.1	1700-1850	*M*	0.00001042	.....
60 C., 40 Z.	...	8.36	0.3018	521.7				
50 C., 50 Z.	...	8.20	0.2960	511.6				
Bronze	...	8.85	0.3195	552.2	1675	*B*	0.00001024	.....
Cadmium	Cd	8.60	0.3105	536.6	610	*M*	0.00001755	24.38
Calcium	Ca	1.57	0.0567	98.0	1490	*M*	.....	21.77
Chromium	Cr	6.50	0.2347	405.6	2939	*B*	.....	16.00
Cobalt	Co	8.65	0.3123	539.8	2696	*M*	0.00000687	16.93
Copper	Cu	8.82	0.3184	550.4	1981	*M*	0.00000926	97.67
Gold	Au	19.32	0.6975	1205.6	1945	*M*	0.00000817	76.71
Iridium	Ir	22.42	0.8094	1398.0	4260	*M*	0.00000356	13.52
Iron, cast	Fe	7.20	0.2600	449.2	2300	*B*	0.00000589	.....
Iron, wrought	Fe	7.85	0.2834	489.8	2750	*M*	0.00000648	16.80
Lead	Pb	11.37	0.4105	709.5	621	*S*	0.00001506	8.42
Magnesium	Mg	1.74	0.0628	108.6	1204	*M*	0.00001497	38.44
Manganese	Mn	7.42	0.2679	463.0	2246	*B*	.....	19.75
Mercury (60° F.)	Hg	13.58	0.4902	847.4	−38	*F*	.....	1.75
Molybdenum	Mo	8.56	0.3090	534.2	4620	*B*	.....	17.80
Nickel	Ni	8.80	0.3177	549.1	2646	*M*	0.00000710	12.89
Platinum, rolled	Pt	22.67	0.8184	1414.6	3191	*M*	0.00000499	14.43
Platinum, wire	Pt	21.04	0.7595	1312.9				
Potassium	K	0.87	0.0314	54.3	144	*S*	0.00004611	19.62
Silver	Ag	10.53	0.3802	657.1	1761	*M*	0.00001067	100.00
Sodium	Na	0.98	0.0354	61.1	207	*S*	.....	31.98
Steel	Fe	7.80	0.2816	486.7	2500	*M*	0.00000638	12.00
Tellurium	Te	6.25	0.2256	390.0	846	*B*	0.00002048	0.001
Tin	Sn	7.29	0.2632	454.8	449	*M*	0.00001276	14.39
Titanium	Ti	3.54	0.1278	220.9	3272	*M*	.....	13.73
Tungsten	W	18.77	0.6776	1171.2	6152	*B*	.....	14.00
Vanadium	Va	5.50	0.1986	343.2	3128	*M*	.....	4.95
Zinc, cast	Zn	6.86	0.2476	428.1	787	*B*	0.00001653	29.57
Zinc, rolled	Zn	7.15	0.2581	446.1				

* *B* = brittle; *F* = fluid; *H* = hard; *M* = malleable; *S* = soft.

STANDARD PIPE

Nominal Pipe Diameter, Inches	Actual Inside Diameter, Inches	Actual Outside Diameter, Inches	Inside Area, Square Inches	Weight per Foot, Pounds	Length in Feet Containing One Cubic Foot	U. S. Gallons in One Lineal Foot	Square Feet of Outer Surface per Foot	Length in Feet per Square Foot Inside Surface
1/8	0.269	0.405	0.057	0.244	2526.000	0.0030	0.106	14.200
1/4	0.364	0.540	0.104	0.424	1383.800	0.0054	0.141	10.494
3/8	0.493	0.675	0.191	0.567	754.360	0.0099	0.177	7.748
1/2	0.622	0.840	0.304	0.850	473.910	0.0158	0.220	6.141
3/4	0.824	1.050	0.533	1.130	270.030	0.0277	0.275	4.636
1	1.049	1.315	0.864	1.678	166.620	0.0449	0.344	3.641
1¼	1.380	1.660	1.496	2.272	96.275	0.0777	0.434	2.768
1½	1.610	1.900	2.036	2.717	70.733	0.1058	0.497	2.372
2	2.067	2.375	3.356	3.652	42.913	0.1743	0.622	1.848
2½	2.469	2.875	4.788	5.793	30.077	0.2487	0.753	1.547
3	3.068	3.500	7.393	7.575	19.479	0.3840	0.916	1.245
3½	3.548	4.000	9.887	9.109	14.565	0.5136	1.047	1.077
4	4.026	4.500	12.730	10.790	11.312	0.6613	1.178	0.949
4½	4.506	5.000	15.947	12.538	9.030	0.8284	1.309	0.848
5	5.047	5.563	20.006	14.617	7.198	1.0393	1.456	0.757
6	6.065	6.625	28.890	18.974	4.984	1.5008	1.734	0.630
7	7.023	7.625	38.738	23.544	3.717	2.0124	1.996	0.544
8	7.981	8.625	50.027	28.554	2.878	2.5988	2.258	0.479
9	8.941	9.625	62.786	33.907	2.293	3.2616	2.520	0.427
10	10.020	10.750	78.854	40.483	1.826	4.0963	2.814	0.381
12	12.000	12.750	113.097	49.562	1.273	5.8752	3.338	0.318

DIFFERENT STANDARDS FOR WIRE GAGES IN USE IN THE UNITED STATES

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gage	American, or Brown & Sharpe	Birmingham, or Stubs' Iron Wire	Washburn & Moen, Worcester, Mass.	W.&M. Steel Music Wire	New American S & W Co.'s Music Wire Gage	Imperial Wire Gage	Stubs' Steel Wire	U.S. Standard Gage for Sheet and Plate Iron and Steel	Number of Wire Gage
00000000	.....	.....	.....	.0083	.....	.....	.....	.....	00000000
0000000	.....	.....	.....	.0087	.....	.....	.....	.....	0000000
000000	.....	.....	.....	.0095	.004	.464	.....	.....	000000
00000	.....	.....	.....	.010	.005	.432	.....	.....	00000
0000	.460	.454	.3938	.011	.006	.400	.....	.40625	0000
000	.40964	.425	.3625	.012	.007	.372	.....	.375	000
00	.3648	.380	.3310	.0133	.008	.348	.....	.34375	00
0	.32486	.340	.3065	.0144	.009	.324	.....	.3125	0
1	.2893	.300	.2830	.0156	.010	.300	.227	.28125	1
2	.25763	.284	.2625	.0166	.011	.276	.219	.26562	2
3	.22942	.259	.2437	.0178	.012	.252	.212	.2391	3
4	.20431	.238	.2253	.0188	.013	.232	.207	.2242	4
5	.18194	.220	.2070	.0202	.014	.212	.204	.2092	5
6	.16202	.203	.1920	.0215	.016	.192	.201	.1943	6
7	.14428	.180	.1770	.023	.018	.176	.199	.1793	7
8	.12849	.165	.1620	.0243	.020	.160	.197	.1644	8
9	.11443	.148	.1483	.0256	.022	.144	.194	.1495	9
10	.10189	.134	.1350	.027	.024	.128	.191	.1345	10
11	.090742	.120	.1205	.0284	.026	.116	.188	.1196	11
12	.080808	.109	.1055	.0296	.029	.104	.185	.1046	12
13	.071961	.095	.0915	.0314	.031	.092	.182	.0897	13
14	.064084	.083	.0800	.0326	.033	.080	.180	.0747	14
15	.057068	.072	.0720	.0345	.035	.072	.178	.0673	15
16	.05082	.065	.0625	.036	.037	.064	.175	.0598	16
17	.045257	.058	.0540	.0377	.039	.056	.172	.0538	17
18	.040303	.049	.0475	.0395	.041	.048	.168	.0478	18
19	.03589	.042	.0410	.0414	.043	.040	.164	.0418	19
20	.031961	.035	.0348	.0434	.045	.036	.161	.0359	20
21	.028462	.032	.03175	.046	.047	.032	.157	.0329	21
22	.025347	.028	.0286	.0483	.049	.028	.155	.0299	22
23	.022571	.025	.0258	.051	.051	.024	.153	.0269	23
24	.0201	.022	.0230	.055	.055	.022	.151	.0239	24
25	.0179	.020	.0204	.0586	.059	.020	.148	.0209	25
26	.01594	.018	.0181	.0626	.063	.018	.146	.0179	26
27	.014195	.016	.0173	.0658	.067	.0164	.143	.0164	27
28	.012641	.014	.0162	.072	.071	.0149	.139	.0149	28
29	.011257	.013	.0150	.076	.075	.0136	.134	.0135	29
30	.010025	.012	.0140	.080	.080	.0124	.127	.0120	30
31	.008928	.010	.0132	.....	.085	.0116	.120	.01094	31
32	.00795	.009	.0128	.....	.090	.0108	.115	.01016	32
33	.00708	.008	.0118	.....	.095	.0100	.112	.00938	33
34	.006304	.007	.0104	.....	.100	.0092	.110	.00859	34
35	.005614	.005	.0095	.....	.106	.0084	.108	.00781	35
36	.005	.004	.0090	.....	.112	.0076	.106	.00703	36
37	.004453	.....	.....	.....	.....	.0068	.103	.00664	37
38	.003965	.....	.....	.....	.....	.0060	.101	.00625	38
39	.003531	.....	.....	.....	.....	.0052	.099	.....	39
40	.003144	.....	.....	.....	.....	.0048	.097	.....	40

TAP DRILL DIAMETERS

For U. S. Standard Thread Form—Standard Pitches Marked with Stars*

Screw Thread Diameter	Threads per Inch	Tap Drill: Size or Number	Tap Drill: Decimal Equivalent	Root Diameter of Thread
1/4	20*	7	0.2010	0.1850
	24	4	0.2090	0.1959
	27	3	0.2130	0.2019
	28	3	0.2130	0.2036
	32	7/32	0.2187	0.2094
5/16	18*	F	0.2570	0.2403
	20	17/64	0.2656	0.2476
	24	I	0.2720	0.2584
	27	J	0.2770	0.2644
	32	9/32	0.2812	0.2719
3/8	16*	5/16	0.3125	0.2938
	20	21/64	0.3281	0.3100
	24	Q	0.3320	0.3209
	27	R	0.3390	0.3269
7/16	14*	U	0.3680	0.3447
	20	25/64	0.3906	0.3726
	24	X	0.3970	0.3834
	27	Y	0.4040	0.3894
1/2	12	27/64	0.4219	0.3918
	13*	27/64	0.4219	0.4001
	20	29/64	0.4531	0.4351
	24	29/64	0.4531	0.4459
	27	15/32	0.4687	0.4519
9/16	12*	31/64	0.4844	0.4542
	18	33/64	0.5156	0.4903
	27	17/32	0.5312	0.5144
5/8	11*	17/32	0.5312	0.5069
	12	35/64	0.5469	0.5168
	18	37/64	0.5781	0.5528
	27	19/32	0.5937	0.5769
11/16	11*	19/32	0.5937	0.5694
	16	5/8	0.6250	0.6063
3/4	10*	21/32	0.6562	0.6201
	12	43/64	0.6719	0.6418
	16	11/16	0.6875	0.6688
3/4	27	23/32	0.7187	0.7019
13/16	10*	23/32	0.7187	0.6826
7/8	9*	49/64	0.7656	0.7307
	12	51/64	0.7969	0.7668
	14	13/16	0.8125	0.7822
	18	53/64	0.8281	0.8028
	27	27/32	0.8437	0.8269
15/16	9*	53/64	0.8281	0.7932
1	8*	7/8	0.8750	0.8376
	12	59/64	0.9219	0.8918
	14	15/16	0.9375	0.9072
	27	31/32	0.9687	0.9519
1 1/8	7*	63/64	0.9844	0.9394
	12	1 3/64	1.0469	1.0168
1 1/4	7*	1 7/64	1.1094	1.0644
	12	1 11/64	1.1719	1.1418
1 3/8	6*	1 7/32	1.2187	1.1585
	12	1 19/64	1.2969	1.2668
1 1/2	6*	1 11/32	1.3437	1.2835
	12	1 27/64	1.4219	1.3918
1 5/8	5 1/2*	1 29/64	1.4531	1.3888
1 3/4	5*	1 9/16	1.5625	1.4902
1 7/8	5*	1 11/16	1.6875	1.6152
2	4 1/2*	1 25/32	1.7812	1.7113
2 1/8	4 1/2*	1 29/32	1.9062	1.8363
2 1/4	4 1/2*	2 1/32	2.0312	1.9613
2 3/8	4*	2 1/8	2.1250	2.0502
2 1/2	4*	2 1/4	2.2500	2.1752
2 3/4	4*	2 1/2	2.5000	2.4252
3	3 1/2*	2 23/32	2.7187	2.6288
3 1/4	3 1/2*	2 31/32	2.9687	2.8788
3 1/2	3 1/4*	3 3/16	3.1875	3.1003
3 3/4	3*	3 7/16	3.4375	3.3170
4	3*	3 11/16	3.6875	3.5670

The commercial tap drill sizes listed are based upon 75 per cent full thread depth—Adopted by tap and die manufacturers